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Voyager Electronic Parts Radiation Program

Volume II: Test Requirements and Procedures

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PREFACE

The work described in this report was performed by the Information Systems Division of the Jet Propulsion Laboratory under the cognizance of the Voyager Project.

Documents outlining the conditions and requirements of the test program, which make up Appendixes A through E of this report, are published here as Volume II. These Appendixes are as follows:

Appendix A -- Electron Simulation Radiation Test Specification for Voyager Electronic Parts and Devices

Appendix B -- Electronic Piece-Part Testing Program for Voyager

Appendix C -- Test Procedure for Radiation Screening of Voyager Piece Parts

Appendix D -- Boeing In Situ Test Fixture

Appendix E -- Irradiate - Anneal (IRAN) Screening Documents

The Voyager Project was formerly designated the Mariner Jupiter/Saturn 1977 Project, and some of the publications cited in this report bear the earlier Project nomenclature.

ABSTRACT

Test requirements and procedures for the Voyager electronic parts radiation program are set forth in detail as Appendixes to JPL Publication 77-41, Volume I. Together, the two volumes describe the program philosophy, radiation environment, device hardening efforts, and radiation test methods. Test results of more than 200 device types are summarized in Volume I.

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APPENDIX A

ELECTRON SIMULATION RADIATION TEST SPECIFICATION FOR VOYAGER ELECTRONIC PARTS AND DEVICES*

A. Scope

This specification establishes the Jovian electron simulation radiation test requirements for shielded parts and devices used in the Voyager spacecraft. These requirements are based on the Voyager design requirements for electronic parts contained in the spacecraft bus. These parts are protected by the inherent shielding provided by the subsystem structure as well as any mass shielding used to reduce the radiation levels within the subsystem. Consequently, the requirements should not be used in conjunction with any subsystem or system level radiation tests or any other radiation tests designed to evaluate materials or devices which are exposed to the external radiation environment.

The electron radiation test consists of:

a) Radiation damage tests

b) Radiation induced electronic noise background tests.

In most cases b) is not required since the interference effects caused by photocurrents are negligible. This is because the photocurrents generated are powers of magnitude smaller than the operating currents.

The major exception to this rule is provided by sensitive photodetectors capable of detecting single photons. Interference effects in such devices must be measured in a separate test program reflecting actual operating conditions of the systems. A ^{60}Co source provides a suitable radiation environment for this purpose.

B. Applicable Documents

"Mariner Jupiter/Saturn 1977 Environmental Design Requirements, "Rev. A, by Tom Gindorf, Oct. 13, 1976, in MJS77 Functional Requirements, 618-205, (various dates), Jet Propulsion Laboratory, Pasadena, California, (JPL internal document).

C. Requirements

1. Parts to be Tested

Parts or devices to be tested shall be selected by the Electronic Parts Engineering Section in conjunction with the Voyager

*This Appendix was originally published as Appendixes C and E of Ref. A-1.

subsystem Cognizant Engineer from the Voyager parts list or alternative parts under consideration. As a goal, the number of samples of each part type to be tested shall be sufficiently large to provide meaningful statistical results on performance. Furthermore, the parts should be of flight quality, traceable to a manufacturer's lot number, and have been previously tested electrically to verify their adherence to manufacturer's specifications. When flight quality parts are not available, commercially available parts may be used, but the quality of the parts and the screening procedure shall be noted in the test plan.

a) Unit Mechanical Configuration

Parts or devices shall be in their mechanical configuration as received from the manufacturer. Particularly, parts or devices shall be in their regular can to insure mechanical integrity and protection. However, no additional shielding shall be provided during the radiation test.

b) Unit Electrical Operating Mode

During the radiation test the parts or devices shall have electrical bias applied which represents the worst case electrical mode of the parts during operation with respect to radiation effects.

c) Unit Performance

The parts and devices shall conform to the requirements and specifications of the pertinent manufacturer. The electrical measurements which determine the acceptance or failure of the parts and devices will be established by the Electronic Parts Engineering Section in conjunction with the pertinent Voyager subsystem Cognizant Engineer and documented in the detailed test plan.

d) Preirradiation Functional Test

All parts and devices shall be electrically tested prior to irradiation testing to demonstrate that their performance characteristics are within the requirements specified in paragraph c). These electrical tests shall be identical to the postirradiation electrical tests.

2. Radiation Classification of Parts

Parts and devices shall be classified as to the type of radiation damage to which they are most susceptible in accordance with Table A-1, which is a summary of the categories of parts and required test environments.

Table A-1. Category of Parts and Required Test Environments

Parts Group	Predominant Effect Expected	Test Environment Required	Parts
Group I	Ionization	Gammas or Electrons	MOSFETS MOS IC CMOS IC JFET (I_{GS} and I_{DSS} only) SCR (except breakover voltage) Optical Materials Small Signal Bipolar Transistors with $f_T > 10$ MHz and in use emitter current density < 0.1 a/cm^2 (Except inverse beta).
Group II			
a.	Combined Ionization and Displacement	Electron	Unijunction Transistor Phototransistor Photodiode (LED) OP AMP Chopper Transistor Inverse Beta for any Transistor Detectors Matched Dual Transistors (Bipolar of JFET) Bipolar Transistors with $f_T < 10$ MHz or in use emitter current density > 0.1 a/cm^2 or unknown emitter area. SCR (breakover voltage)
b.	Displacement	Electron	

3. Radiation Tests

Four types of radiation tests are defined:

a) Ionization Damage.

b) Combined Ionization and Displacement Damage.

c) Bulk Displacement Damage.

d) Radiation Induced Electronic Noise Background.

Each of these tests is specified with appropriate test levels at which the parts shall demonstrate a capability as defined in Ref. A-1. For those parts which are not expected to have a capability at the design requirement, additional lower test levels may be required for characterization.

a) Ionization Damage

Parts and devices which are primarily sensitive to ionization damage shall be tested to evaluate damage at the radiation levels specified in Table A-2 as a minimum, using either a ^{60}Co gamma source or a steady-state dc electron accelerator, whichever is more practical. If the tests are to be performed using a dc electron accelerator, the electron flux shall have an energy sufficient to penetrate the can, housing, chassis, or other structural material shielding the sensitive electronic material of the part or device. It should be noted that the total accumulated fluence and dose in Table A-2 are the summation of fluences and doses obtained by performing each of the 3 exposures sequentially. Table A-7 or Figure A-1 shall be used to calculate dose from electrons.

If tests are to be performed using a ^{60}Co gamma source the test parts shall be covered with a thickness of Lucite, Teflon, or equivalent material in the amount of 450 mg/cm^2 to provide buildup of electronic equilibrium at the surface of the test part.

b) Combined Ionization and Displacement Damage

Parts and devices which are sensitive to both displacement damage and ionization damage shall be tested to evaluate damage at the radiation levels specified in either Table A-2 or Table A-3 as a minimum depending on electron energy (as described below) using a steady-state dc

Table A-2. Ionization Damage Radiation Levels for Testing Voyager Parts (Sequential Testing)

	Electrons			^{60}Co	
Exposure Time (s)	Electron Energy (MeV)	Electron Flux (e/cm^2-s)	Total Accumulated Fluence (e/cm^2)	Dose Rate [rad(Si)/s]	Total Accumulated Dose [rad(Si)]
1. 1000	3	1.2 (9)	1.2 (12)	30	3.0 (4)
2. 1000	3	1.2 (9)	2.4 (12)	30	6.0 (4)
3. 1000	3	2.4 (9)	4.8 (13)	60	1.2 (5)

Table A-3. Displacement Damage Radiation Levels for Testing Voyager Parts, Using 3-MeV Electrons Incident on the Test Part (Sequential Testing)

Exposure Time (s)	Incident Energy (MeV)	Electron Flux (e/cm^2-s)	Fluence per Irradiation (e/cm^2)	Total Accumulated Fluence (e/cm^2)
1000	3	1.2 (9)	1.2 (12)	1.2 (12)
1000	3	1.2 (9)	1.2 (12)	2.4 (12)
1000	3	2.4 (9)	2.4 (12)	4.8 (12)

electron accelerator which produces a flux of electrons having sufficient energy to penetrate the can, housing, chassis, or other structural material which shields the sensitive electronic material of the part or device. The dose and fluence levels of Table A-2 and Table A-3, respectively, are based on an electron energy of 3 MeV and sequential testing.

The ionization effects produced by electrons in the energy range of 1 MeV to 5 MeV are essentially identical, but the higher energy electrons produce greater displacement damage. In parts which are sensitive to both types of damage the two effects cannot be separated.

If the incident electron energy is 3 MeV, the ionization dose and displacement fluence requirements specified in Tables A-2 and A-3 will be satisfied concurrently at an accumulated electron fluence of 4.8×10^{12} e/cm^2. If the incident electron energy is less than 3 MeV the fluence requirements in Table A-3 will be controlling. The ionization dose requirement will be fulfilled at a fluence of about 4.8×10^{12} e/cm^2 (adjusted for the relative ionization dose conversion factors from Table A-7 or Figure A-1) but the displacement damage will be low. Therefore, it will be necessary to increase the fluence levels in Table A-3 by applying the appropriate conversion factor from Table A-7 or Figure A-1 such that the final exposure will yield an accumulated fluence of 4.8×10^{12} e/cm^2 of 3-MeV equivalent electrons. In this case the total dose will be greater than 1.2×10^5 rad(Si).

Conversely, if the incident electron energy is greater than 3 MeV the dose requirements of Table A-2 will be controlling. The fluence in Table A-2 required to produce the necessary doses will be determined by applying the appropriate ionization dose conversion factors from Table A-7 or Figure A-1. In this case the dose requirements of Table A-2 will be fulfilled and the displacement fluence will be greater than the requirements of Table A-3.

c) Bulk Displacement Damage

Parts and devices which are primarily sensitive to bulk displacement damage shall be tested using a steady-state dc electron accelerator which produces a flux of electrons having sufficient energy to penetrate the shielding material and enter the sensitive electronic material with energy $\sim$4.5 MeV. The flux and fluence levels of Table A-4 are based on a 4.5 MeV incident beam. If the energy is different from 4.5 MeV, the flux and fluence levels in Table A-4 require adjustment to correspond to the appropriate energy. If required, these new flux and fluence levels may be obtained from Table A-7 or Figure A-1.

It should be noted that the accumulated fluence levels in Table A-4 are the summation of the fluences obtained by performing each of the 3 exposures sequentially so that the test part performance evaluations can be made after each radiation level.

d) Radiation Induced Electronic Noise Background

Rate interference tests shall be conducted using a steady-state dc electron accelerator or a ^{60}Co gamma source to simulate ionizing radiation. Electron fluxes and ^{60}Co gamma dose rates are contained in Table A-5. Electrons shall have sufficient energy to penetrate any covering or shielding materials which may be protecting the rate sensitive material or device and shall be in the energy range 1 MeV to 5 MeV. Flux to dose rate conversion factors can be obtained from Table A-7 or Figure A-1.

D. Test Levels

Tables A-2, A-3, and A-4 contain the required minimum radiation test levels for evaluating Voyager parts. The maximum test level shall not exceed a fluence of 5×10^{12} electrons/cm^2 (3-Mev equivalent) for displacement damage or a dose of 1.2×10^5 rad(Si) for ^{60}Co gamma irradiations for ionization damage. For parts that are very sensitive to radiation damage, it may be desirable to characterize their performance by adding additional lower fluence levels to the required test levels. For electron damage tests, a flux shall be selected such that the required fluence is not reached before an exposure time of 15 minutes (900 seconds).

E. Dosimetry

1. General Requirements

Prior to radiation testing in any environment a flux map of the pertinent area shall be made to ascertain that the flux uniformity over the test part meets the requirements specified in Table A-6. Table A-6 sets the upper tolerance

Table A-4. Displacement Damage Radiation Levels for Testing Voyager Parts, Using 4.5 MeV-Electrons Incident on the Test Part (Sequential Testing)

Exposure Time (s)	Incident Energy (MeV)	Electron Flux (e/cm^2-s)	Fluence per Irradiation (e/cm^2)	Total Accumulated Fluence (e/cm^2)
1. 1000	4.5	1.0 (9)	1.0 (12)	1.0 (12)
2. 1000	4.5	1.0 (9)	1.0 (12)	2.0 (12)
3. 1000	4.5	2.0 (9)	2.0 (12)	4.0 (12)

Table A-5. Radiation Induced Electronic Noise Background Fluxes and Dose Rates for Testing Voyager Parts or Devices

Exposure Time (s)	1 MeV-5 Mev Electron Flux (e/cm^2-s)	Total Accumulated Fluence (e/cm^2)	Gamma Dose Rate [rad(Si)/s]	Total Accumulated Dose [rad(Si)]
1. 600	2.5 (7)	1.5 (10)	0.625	3.7 (2)
2. 600	5.0 (7)	4.5 (10)	1.25	1.1 (3)
3. 600	1.0 (8)	1.0 (11)	2.5	2.6 (3)
4. 600	2.0 (8)	2.2 (11)	5.0	5.6 (3)

Table A-6. Tolerance Limits for Radiation Tests

ELECTRON TEST

The following dosimetry requirements in the free field environment at the test part apply to tests performed with electrons:

PARAMETER	TOLERANCE (%)
Energy Measurement	±10
Flux and Fluence Measurement	±10
Test Beam Uniformity at Test Article Location	±10
Dose Measurement	±15

^{60}Co TEST

The following dosimetry requirements apply to tests performed with ^{60}Co:

PARAMETER	TOLERANCE (%)
Specified Dose and Dose Rate	±10
Dose and Dose Rate Measurement	±15
Dose Uniformity at Test Article Location	±5

NOTE: When using TLDs, the tolerance specified for dose measurement includes both the uncertainty in reading the TLD response and the uncertainty in calibration of the ^{60}Co source.

limit for different parameters involved in a radiation test. In no event shall the compounding of errors lead to an overall tolerance which exceeds ±20%. The personnel conducting the test at the contracting test facility shall demonstrate their capability to measure the exposure of all test parts to within ±20% of the levels specified in Tables A-2, A-3, and A-4.

2. Electron Irradiation of Test Parts

The primary standard for performing dosimetry during electron irradiation of test parts shall be a Faraday cup. The Faraday cup will measure the electron flux at the test part, and integration of the flux over the exposure time will yield the total electron fluence. The fluence-to-dose conversion factor specified in Table A-7 or Figure A-1 shall be used to calculate total dose.

Additional dosimetry shall be used along with the Faraday cup. Calibrated LiF TLDs (thermoluminescent dosimeters), in groups of at least 4 samples each, shall be mounted on a 2.54-cm (1-inch) thick polyurethane or styrofoam using doublebacked tape and placed upon the front face of the Faraday cup and at other strategic locations on the test fixture which, because of its physical size or construction, may receive a dose which may not necessarily correlate with the fluence at the Faraday cup. The TLDs shall be from a manufacturer's lot from which samples have been exposed to a well calibrated ^{60}Co gamma source and for which a calibration curve of TL reading as a function of dose is well defined.

The LiF TLDs should not be exposed to doses greater than 1.2×10^5 rad(Si) to remain within an uncertainty band of ±15%. Exposure to larger doses may increase the uncertainty band to much greater limits depending upon the characteristics of the particular batch of TLDs used.

TLDs shall be kept in the dark at room temperature until their TL response is read, at which time the same TLD reader used for the calibration of the TLDs shall be used.

3. Gamma Exposure of Test Parts

The area exposed by the gamma source shall be well mapped, as described in Section A-5 (Calibration of ^{60}Co Gamma Source Used to Calibrate TLDs) to ascertain that the flux uniformity over the test article meets the requirements of Table A-6.

If the gamma source is such that an ion chamber cannot be used for its direct calibration, then the appropriate TLDs selected from a previously calibrated lot, in groups of 10 samples contained in the appropriate thickness of buildup material (450 mg/cm^2), shall be exposed to the gamma source for a sufficiently long period of time so that any dead time is insignificant. This calibration shall be repeated to provide a minimum of 4 calibrations of the gamma source, preferably for a time period such that the expected dose lies on the near-linear portion of the TL response vs. dose calibration curve.

During exposure of test parts dosimetry shall be performed using TLDs, as described in Section A-2 (Electron Irradiation of Test Parts) except that the TLDs shall be contained or covered by suitable buildup material of Lucite or Teflon, as described in Section A-4 (Calibration of Thermoluminescent Dosimeters).

4. Calibration of Thermoluminescent Dosimeters (TLDs)

TLDs to be calibrated shall be selected from a large lot obtained from the manufacturer so that sufficient TLDs remain for dosimetry during future radiation exposure testing of parts. TLDs, in groups of 10 samples, shall be exposed to a well-calibrated ^{60}Co gamma source for sufficiently long time periods so that any dead time during the exposure period is insignificant (<1%). The samples shall be placed at convenient distances from the source so as to generate a well-defined calibration curve of TL reading versus dose over the dose range of interest. During calibration of TLDs, an ion chamber shall be placed at a convenient distance from the source as a check on the gamma dose during the calibration exposure.

TLDs shall be contained in or covered by a suitable thickness of Lucite or Teflon to assure a buildup of electron equilibrium at the TLD (generally 450 mg/cm^2 for ^{60}Co). Ion chambers shall also be contained in a suitable material to maintain electron equilibrium (generally 4.8-mm (3/16-inch) thick Bakelite).

The TL response of LiF TLDs shall be read during the time interval between 3 hours and 12 days following exposure. TLDs shall be kept in the dark and at room temperature until the TL response is read.

5. Calibration of ^{60}Co Gamma Source Used to Calibrate TLDs

The ^{60}Co source used for calibrating the TLDs shall be well characterized with the use of recently calibrated ion chambers traceable to the National Bureau of Standards and exposed to the gamma radiation for sufficiently long time periods so that any dead time during the exposure period is insignificant (<1%). The ion chambers shall be placed at various distances from the ^{60}Co source to verify the 1/distance^2 relationship. The ion chambers shall be contained in a suitable container to assure buildup of electronic equilibrium, generally 4.8-mm (3/16-inch) thick Bakelite. A minimum of 4 exposures at each position shall be performed to calibrate the gamma source.

F. Parts Radiation Characterization Test Requirements

The Parts Radiation Characterization Test Requirements shall be prepared by or submitted to the Information Systems Division prior to a radiation test. Explicit details of testing a given family of parts may be referenced to a previously approved radiation test requirements document. The test requirements shall indicate the parts to be tested and include details of pre-, during, and post-irradiation electrical mesurements, sample size, disposition, and test sequencing. The influence of annealing after static irradiations shall be demonstrated, or shown to be negligible prior to testing, or a discussion is required as to how the test results will be used to evaluate or demonstrate annealing. The test requirements shall also specify the radiation environment to be used, the flux and fluence or dose expected, the type of dosimetry planned and the location of the dosimeters with respect to the test part and irradiation source.

Electrical parameters which will determine the acceptance or failure of the parts or devices shall be specified prior to the irradiation tests. The detailed test requirements shall also state the methods of data reduction to evaluate performance and establish a schedule for a written report following each test or series of tests.

Test parts irradiated to these specifications shall have no additional shielding provided beyond that inherent in the design and construction of the part itself. Test parts which satisfy the shielding limitation, but have inherent shielding equivalent to approximately 100 mils Al, shall be reviewed for irradiation in a ^{60}Co gamma test or other high energy electron test.

G. Test Regulation and Control

Any deviations or modifications to these Radiation Test Specifications shall be approved by the Voyager Environmental Requirements Engineer.

Detailed test procedures and test setups shall be reviewed by the Voyager Environmental Requirements Engineer.

H. Radiation Equivalence and Correlation

1. Radiation Equivalence Factors

Table A-7 and Figures A-1 through A-4 contain charged particle displacement damage factors and ionization dose conversions. Table A-7 provides listings of the equivalent displacement damage factors for protons, electrons, and neutrons, and the fluence to ionization dose conversion factors for protons, electrons, neutrons, and gammas. Figures A-1 through A-4 contain plots of the tabulated data for user convenience.

Table A-7. Equivalent Displacement Damage and Ionization Dose Conversion Factors

E (MeV)	Protons, Ionization [rad(Si)/p-cm^{-2}]	Protons, 20-MeV Equivalent Displacement	Electrons, Ionization [rad(Si)/e-cm^{-2}]	Electrons, 3-MeV Equivalent Displacement	Neutrons, Ionization [rad(Si)/n-cm^{-2}]	Neutrons, 1-MeV Equivalent Displacement	Gammas, Ionization [rad(Si)/γ-cm^{2}]
0 01	1.00-5	354 0	2 70-7	0	-	-	5.35-9
0.015	1.00-5	253 0	2 00-7	0	-	-	2 10-9
0.02	1.00-5	173 0	1 62-7	0	-	-	1 10-9
0 03	1.00-5	114.0	1 26-7	0	-	-	5 00-10
0.045	1.00-5	74.3	8.94-8	0	1.0-12	0.10	2 35-10
0.065	8.50-6	50 4	6.92-8	0	1 1-12	0 10	1.31-10
0.10	6.90-6	31.7	5 23-8	0	1.0-12	0 10	7.35-11
0.15	6 11-6	20 4	4.14-8	.033	5 0-13	0 10	7.49-11
0.20	5.60-6	14.9	3 60-8	.050	1 7-11	0.83	9.37-11
0.30	4 85-6	9.42	3 04-8	0.087	1 0-11	0.71	1.47-10
0.45	4.12-6	5.91	2.70-8	0 15	1.1-11	0.83	2 15-10
0.65	3.44-6	3.82	2 53-8	0.23	1 7-11	1 70	3.06-10
1.00	2.82-6	2.26	2 45-8	0 38	2.0-11	1 00	4.43-10
1 50	2 17-6	2.26	2.42-8	0.57	2 7-11	1 25	6 07-10
2.00	1.81-6	2.26	2.45-8	0 73	3.2-11	1 37	7 70-10
3.00	1.36-6	2.26	2 50-8	1.00	5 6-11	1 60	1 05-9
4 50	1.01-6	1.77	2 58-8	1.23	8 4-11	1 83	1.45-9
6.50	7.72-7	1.49	2 64-8	1 49	6.0-10	2.00	1.88-9
10.0	5.57-7	1.28	2.72-8	1.84	1 0-9	2.16	2 60-9
15 0	4.07-7	1.15	2 78-8	2.24	7 0-10	2 30	4 18-9
20.0	3.25-7	1.00	2 83-8	2 57	-	-	5 54-9
30.0	2.36-7	0 920	2 90-8	3.13	-	-	8 40-9
45.0	1.72-7	0.745	2 96-8	3 82	-	-	-
65 0	1 29-7	0 563	3.01-8	4 56	-	-	-
100.0	9.37-8	0.345	3.07-8	5.63	-	-	-

Note: 1 00-5 = 1.00 x 10^{-5}

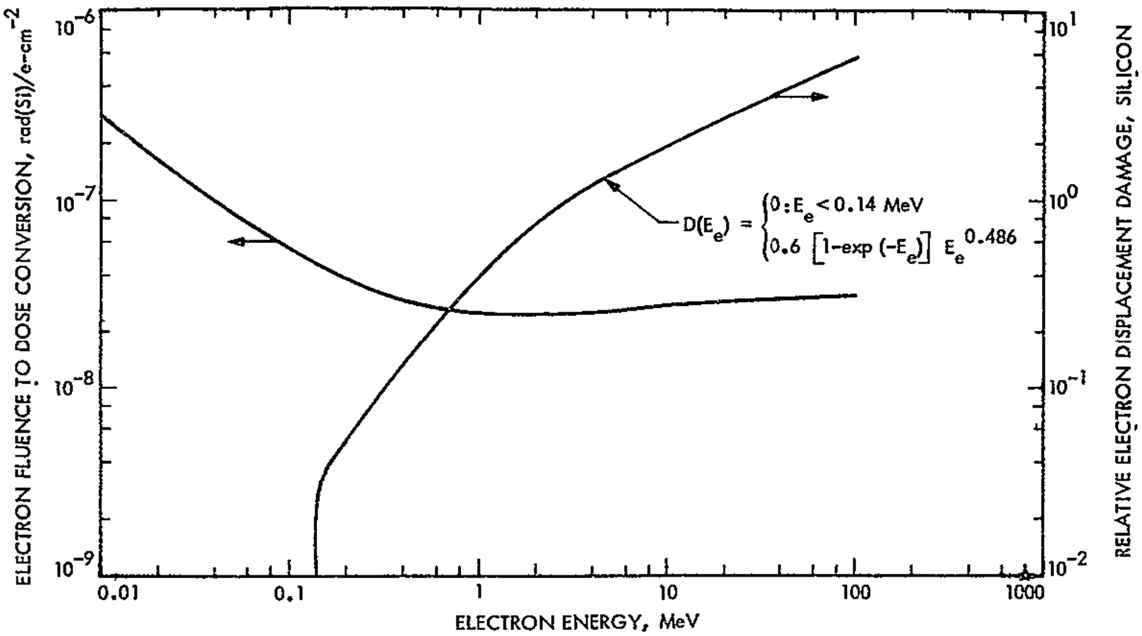

Figure A-1. Ionization Energy Deposition and 3-MeV Electron Equivalent Displacement Damage in Silicon

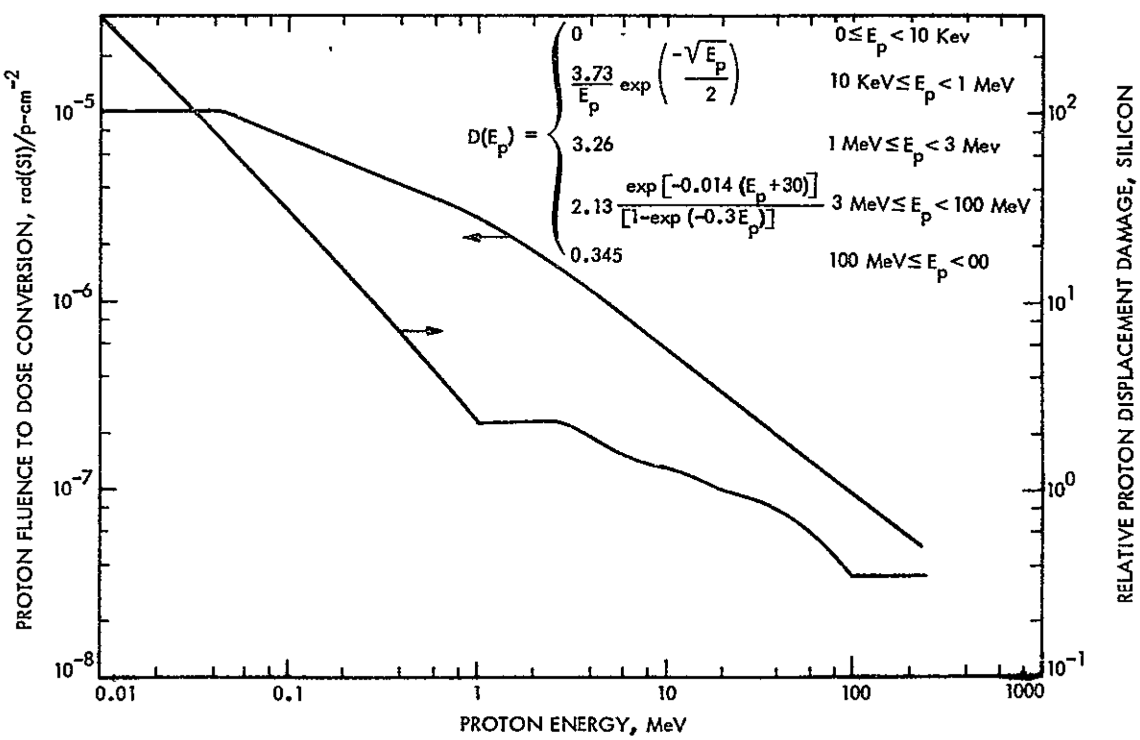

Figure A-2. Ionization Energy Deposition and 20-MeV Proton Equivalent Displacement Damage in Silicon

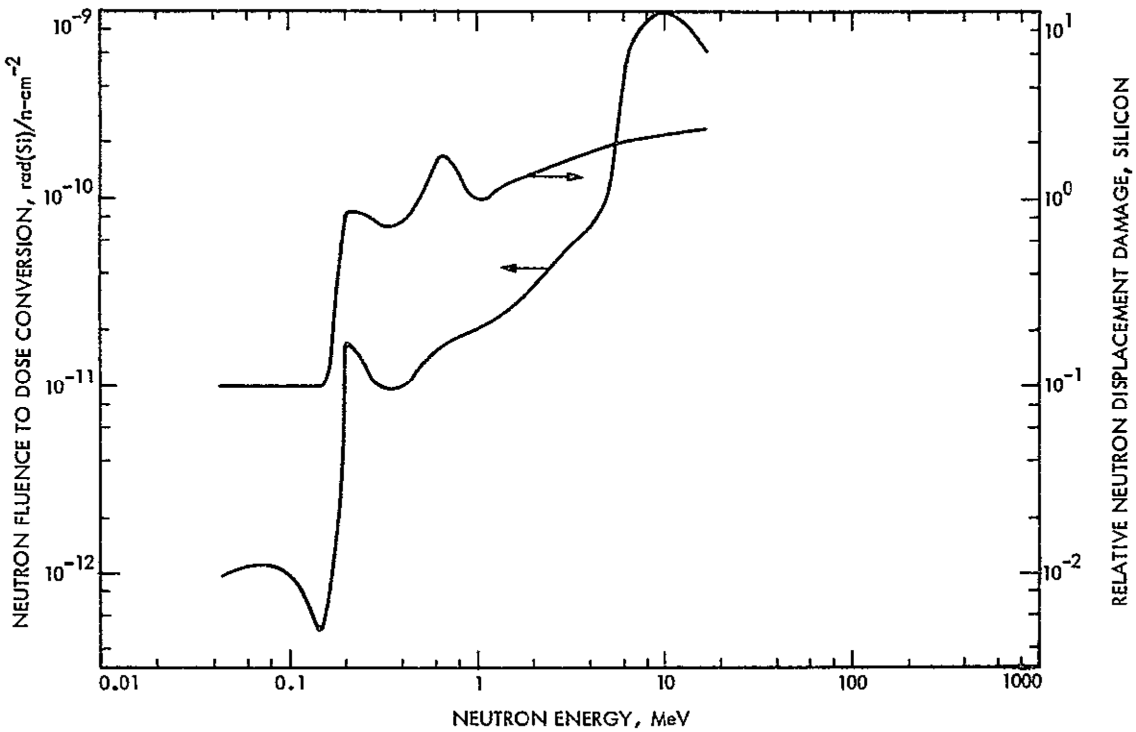

Figure A-3. Ionization Energy Deposition and 1-MeV Neutron Equivalent Displacement Damage in Silicon

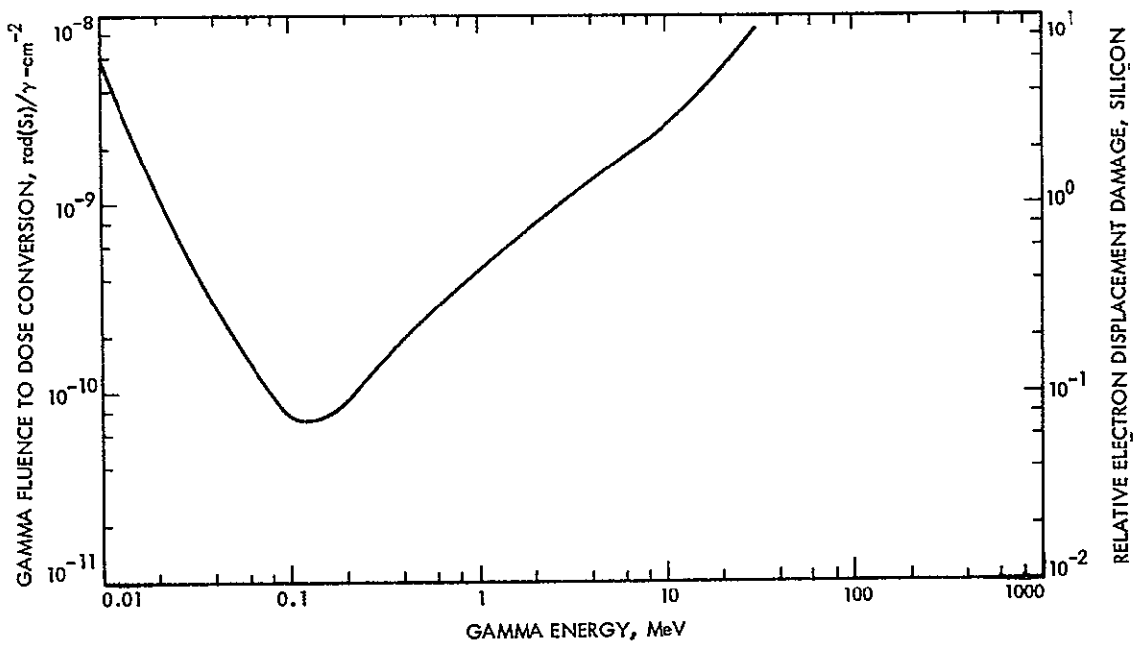

Figure A-4. Gamma Ionization Energy Deposition in Silicon

2. Particle Radiation Damage Correlation

A study was performed in which correlation factors were developed for relative displacement effects produced by electrons, protons, and neutrons in silicon. The correlation was based on the degradation of excess lifetime as a function of injection level* obtained from available data in existing literature. Lifetime damage constants were calculated and, subsequently, damage constant ratios for the particles mentioned above were obtained.

The results generally showed that damage constants decreased with increasing injection level and that damage constant ratios, referred to neutrons, increased with increasing injection level. It may be concluded, therefore, that the damage constants depend upon differences in the injection levels.

Damage constants are summarized in Tables A-8 through A-10 and Table A-11 summarizes the estimates of the relative effectiveness for causing displacement damage in silicon. However, great care should be exercised in applying these correlation factors in predicting radiation effects on electronics because of the uncertainties associated with the constants derived.

*Injection level is the unitless ratio of the excess carrier concentration of the minority charge carriers to the equilibrium carrier concentration of the minority carriers.

Table A-8. 1-MeV Neutron Damage Constants, K_T (cm^2/s)

Resistivity (ohm-cm)	Injection Level 10^{-5}	10^{-3}	10^{-1}	10^{0}
n-type				
1	1×10^{-5}	5×10^{-6}	2×10^{-6}	1.5×10^{-6}*
10	6×10^{-6}	3×10^{-6}	1.5×10^{-6}	1×10^{-6}
100	1×10^{-5}	2.5×10^{-6}	5×10^{-7}	3×10^{-7}
p-type				
1	8×10^{-6}	2×10^{-6}	5×10^{-7}	3×10^{-7}*
10	8×10^{-6}	2×10^{-6}	5×10^{-7}	3×10^{-7}
100	2.5×10^{-6}	1.5×10^{-6}	5×10^{-7}	

* Estimated from trends.

Table A-9. 3-MeV Electron Damage Constants $K_T(cm^2/s)$

Resistivity (ohm-cm)	Injection Level	
	Low ($\leq 10^{-2}$)	High (>1)
n-type		
1	$0.6 - 3 \times 10^{-7}$	$\sim 5 \times 10^{-8}$*
10	$2 - 10 \times 10^{-8}$	$\sim 1 \times 10^{-8}$*
p-type		
1	$1 - 4 \times 10^{-8}$	$2 - 8 \times 10^{-9}$
10	$0.5 - 2 \times 10^{-8}$	$1 - 4 \times 10^{-9}$
100	$\sim 3 \times 10^{-9}$	$\sim 6 \times 10^{-10}$

*Estimated from trends.

Note: A conservative estimate for the range associated with approximate numbers (indicated by ~) is a factor of three above and below the value given.

Table A-10. 20-MeV Proton Damage Constants, K_T(cm^2/s)

Resistivity (ohm-cm)	Injection Level	
	10^{-3}	10^{-1}
n-type		
1	$2 - 10 \times 10^{-5}$	$1 - 5 \times 10^{-5}$
10	-	$\sim 5 \times 10^{-6}$
100	-	-
p-type		
1	$1 - 3 \times 10^{-5}$	$\sim 1 \times 10^{-5}$
10	-	$\sim 5 \times 10^{-6}$

Note: A conservative estimate for the range associated with approximate numbers (indicated by ~) is a factor of three above and below the value given.

Table A-11. Summary of Estimates of Relative Displacement Effectiveness in Silicon (relative fluence needed to cause equal displacement damage in silicon)

Silicon Type	Protons 20 MeV	Electrons 3 MeV	Neutrons 1 MeV
n-type	1	70 - 1600	2 - 25
p-type	1	300 - 1000	4 - 60

Note: The relative effectiveness is dependent upon the injection level and the resistivity of n-type and p-type silicon. If the injection level and/or resistivity are known, the relative displacement effectiveness can be determined more accurately from the data in Tables A-8 to A-10.

REFERENCE

A-1. Mariner Jupiter/Saturn 1977 Radiation Control Requirements Document, PD 618-229, Rev. A, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 19, 1975 (JPL internal document).

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APPENDIX B

PIECE-PARTS TEST PLAN

INTRODUCTION

The Electronic Parts Engineering Section (Section 365) has the responsibility of making recommendations of piece parts to spacecraft subsystem designers which will operate properly in the environments encountered on each mission. For the Voyager spacecraft, there are severe radiation environments, in addition to the usual space environments, which must be considered. The electron environment appears to be the worst for most piece parts and little data presently exists on electron radiation effects to semiconductor devices.

This test will provide performance data on piece parts which can be used to demonstrate acceptable function of critical electrical parameters in $\geq 5 \times 10^{12}$ c/cm^2, 3 MeV equivalent electrons. Where piece parts cannot demonstrate acceptable function within this design requirement and no substitute piece part can be obtained, a part characterization at lower levels will be performed.

Consequently, a crash program has been set up to obtain such information on all devices of concern. While the program will be aimed at obtaining radiation effects data on most semiconductor devices it will be carried out mostly by subcontractors (specifically Boeing and Hughes) under close direction of Section 365 personnel. The data will be obtained by utilizing several radiation sources, principally

(1) Hughes cobalt 60 source

(2) JPL Dynamitron

(3) Boeing Dynamitron

Other sources are contemplated as either backup, in case a primary source breaks down, or in order to do some other types of experiments not being done routinely.

The routine tests described below will be done to (1) characterize the effects of radiation to a particular device type, or (2) to screen diffusion lots. In the case of "screening," fast turn around is an important requirement; that is, it is important to get radiation effects data as soon as possible after receiving a set of devices.

TEST DESCRIPTION

Most tests will be done at room temperature _in situ_, where measurements on device electrical parameters will be made immediately after each radiation exposure. Between 1 and 10 samples will be exposed on one test board (a standard vector board, 11.5 cm x 14 cm, or 4 1/2 x 5 1/2 in.). Two boards can be exposed simultaneously. The limitation on number of samples exposed during one set of exposures is set by the requirement that all property measurements are to be done in about 5 minutes after exposure.

RADIATION DESCRIPTION

For these tests it is desired that the electrons be from a continuous source such as a Van de Graaff or a Dynamitron rather than from a pulsed source as a LINAC provides. The electron energy should be 3 MeV or equivalent. The energy should never be below 2.0 MeV beam port exit energy because of the losses incurred in beam spreading and in penetrating the device casing.

Beam uniformity over the test area shall be within 20% of the test level specified. Beam uniformity characteristics will be checked periodically and reported for that particular test.

The flux and fluence levels may be adjusted if new information on the levels at Jupiter, or if the particular piece part, requires it. The general piece-part radiation test requirements specifies the following 3-MeV equivalent test levels shown in Table B-1.

EXPOSURE PROCEDURE

The first two steps of fluence may sometimes be done in one step at 5×10^9 e/cm^2-sec in 1000 seconds. When the first two steps are combined, a new third step will be assigned at 1000 seconds irradiation time and 5×10^9 e/cm^2-sec at the option of the Radiation Test Group Supervisor, to produce a total accumulation of 2.0×10^{13} e/cm^2. This will allow characterization at other levels when necessary. Since 1000 sec is 16.7 minutes, a series of three exposures, with measurements between, should take the following:

15 - 30 min - setup and checkout

5 min - initial parameter readings

17 min - first exposure

5 min - first post-exposure readings

17 min - second exposure

5 min - second post-exposure readings

17 min - third exposure

5 min - third post-exposure readings

111 min (or about 2 hours)

Table B-1. 3-MeV Equivalent Test Levels

Time For Exposure (sec)	Flux, (e/cm^2-sec)	Accumulated Fluence Levels (e/cm^2)
1000	2.5×10^9	2.5×10^{12}
1000	2.5×10^9	5.0×10^{12}
1000	5.0×10^9	1.0×10^{13}

This would be shorter by 22 minutes if only two exposures are required. It is desired that there is no break in the series once it begins, in order to reduce annealing at room temperature.

RESPONSIBILITIES OF VARIOUS GROUPS

Section 365 is funding the subcontracting work through its Voyager budget and is buying all the parts to be exposed to radiation in the program. These parts are supplied to the subcontractor along with a sheet of Radiation Test Requirements (RTR). The electrical performance requirements are prepared by Section 365 after discussions with cognizant engineers and designers. The RTR will give electrical parameters to be measured and other electrical conditions, including bias during exposure, as well as flux and fluence requirements. After completion of the test and a minor amount of data analysis, the data will be turned over to Section 365 personnel who will transmit it to appropriate Project personnel as necessary.

The subcontractor will build test fixtures, check out the bias and measurement system, place the parts on the fixture, and place the fixtures in position for exposure with proper shielding to assure good data. Subcontractor personnel will travel to radiation sources and supply equipment as required to carry out the program. After exposure they will make electrical parameter measurements on each device as rapidly as possible and do some simple calculations to put the data in a reasonable form for presentation to Section 365 personnel.

The radiation source personnel shall provide the electron or cobalt 60 source on a prearranged schedule where Section 365 personnel can know the schedule at least 2 weeks in advance, and preferably 2 months. They shall provide a faraday cup to make electron/cm^2 measurements to set the absolute test level. The faraday cup will be located in a position defined with respect to the beam uniformity map to insure that all locations in the test beam remain with the ±20% of test level specified.

The above outlines the program of radiation testing being carried out by Section 365. It is expected that in the course of the program hundreds of parts will be tested and that there will be continuous work over the next 6 months to accomplish the initial survey and finally the screening.

The arrangement to be used for the JPL Dynamitron exposures is shown in Figure B-1.

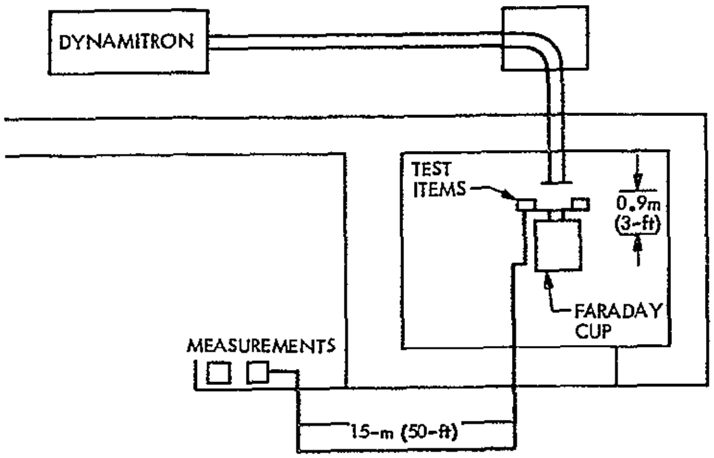

Figure B-1. JPL Dynamitron Test Setup

APPENDIX C

TEST PROCEDURE FOR RADIATION SCREENING OF VOYAGER PIECE PARTS

1.0 SCOPE

This procedure covers radiation screening of Voyager piece parts for lot sample screening and reirradiation of lot samples after Irradiation Anneal (IRAN). The requirements are given herein for parts handling and data recording. Data and parts movement between JPL and the radiation testing contractor are also defined.

2.0 DEFINITIONS

Definitions of terms unique to this program are given below:

(1) IRAN: Irradiation and Anneal program in which flight parts are irradiated with cobalt 60 gammas and then annealed in an oven at 150°C for 4 days.

(2) Lot Screen: Radiation testing program of a sample of piece parts from a particular manufacturer's date code, diffusion run, or wafer.

(3) JFET Radiation Screening: Junction field-effect transistors are irradiated with cobalt 60 gammas and are not subsequently annealed. This is a special case of lot screening.

(4) Reirradiate: Radiation testing program where a sample of a lot previously irradiated in the IRAN or Lot Screen program is reirradiated with electrons to simulate the Voyager exposure to the Jupiter electron belts.

(5) Laboratory Standard: A part which has had its electrical parameters measured by independent means and is used for checkout of the measurement systems used in radiation testing.

3.0 TEST SAMPLES

All test samples shall be semiconductor devices, including integrated circuits, bipolar transistors, and JFET's. Many are samples taken from lots of flight parts which have had a number of tests and measurements prior to the radiation tests (see note below). Several device types are "charge-sensitive," requiring special handling to protect them against static electrical discharge.

NOTE

It is of extreme importance that all Lot Screen and Reirradiate Test parts shall be treated with great care to guard against damage by charge effects or improper test procedures due to their value and scarcity. Most samples are irreplaceable.

All samples shall be provided to the testing contractor by JPL with suitable identification, with a "Traveler" described in Section 9 below, and a Radiation Test Requirement (RTR) described in Section 10. These samples shall be determined by contractor bench tests to be operating samples within JPL or manufacturers' specifications.

When the radiation tests have been completed, the samples shall be returned to JPL along with copies of the raw test data, calculated test data, joint signoff sheet, circuit schematic, traveler, and a sheet listing all test anomalies and the resultant actions taken by the contractor.

4.0 PERSONNEL

Contractor personnel shall be permanently assigned to this task. Changes in personnel shall be agreed to by JPL prior to such change. At least one engineer and one technician shall be the normal complement of the test group. Each member of the test group and any possible substitutes required (due to illness) shall have a green badge assignment for unescorted on-Lab (JPL) use. Personnel shall be required to travel between the contractor's test facilities and JPL.

5.0 FACILITIES

Two facilities will be used in these tests; the JPL Dynamitron and the Hughes 50-kilocurie cobalt 60 source.

At the JPL Dynamitron, the test equipment will be set up on a bench outside the exposure room, using a standard 15-m (50-foot) cable going through the doorway to connect with the test circuit boards inside the exposure room. The test device circuit board shall be placed in a fixture to position it 0.9 m (3 feet) from the emergent beam window. A Faraday cup shall be positioned on center of the beam with circuit card broadside to the beam direction and with the test devices positioned within a 10 cm (4-inch) radius (x-y axis) from the center of the Faraday cup opening. The end of the beam tube shall be covered with 0.05 mm (0.002 in.) of copper and 0.10 mm (0.004 in.) of aluminum, in addition to the 0.05 mm (0.002 in.) titanium beam window. Contractor personnel will assure that the scattering foils are in place for each test.

At the Hughes 50-kilocurie cobalt 60 source the test setup is very similar, and the test equipment is identical. The test devices circuit board shall be placed at a point in the field to give the dose rate specified in the RTR.

6.0 RADIATION MEASUREMENTS

At the JPL Dynamitron, the radiation measurements shall be made with a Faraday cup placed on beam center. The devices under test shall be positioned in the x-y plane in front of the Faraday cup and within 3.8 cm (1.5 in.) in the z-plane of the aperture. The Faraday cup's output shall be integrated with an integrating current meter which shall be calibrated each day of the testing. Periodic measurements shall be made of the beam uniformity in the plane of the devices under test. This shall be done using standard techniques such as thermoluminescent dosimeters (TLD) or a traversing ion chamber. Uniformity over the test area for all tests shall not vary more than 10%. Any changes in geometry shall require a beam uniformity mapping before the test.

Radiation dosimetry at the Hughes cobalt 60 source shall be performed using TLD calibrated by a ±2% ion chamber, with accuracy traceable to the U.S. Bureau of Standards. Measurements of beam uniformity shall be made over the test boards to show that the dose rates on the devices under test do not vary more than 10%.

Doses and fluences used for each test are given on the RTR's. These values shall be obtained in the test to within ±10% for each device under test.

7.0 TEST EQUIPMENT

Test equipment has been built for use in the *in situ* tests in carrying out the characterization tests prior to the screening tests.

This equipment (along with a number of pieces of standard test equipment, including power supplies, a digital voltmeter, a micro-micro ammeter and others) is to be used in the screening tests. Because the tests required on the RTR's vary radically from one type of device to another, the test equipment list will change from time to time.

Calibration of the applicable test equipment shall be done on a routine basis. The contractor's test engineer is responsible for keeping a list of the equipment being used in the screening work and ensuring that recalibration is done as required on each piece of equipment.

As the equipment is used both at the contractor's facility and at JPL, the movements of equipment out of and into each facility shall be covered by shippers. Equipment coming into JPL shall be checked in by the Receiving Group immediately upon arrival and before being taken to the test site.

Test equipment needed to carry out screening tests shall be provided by the contractor. In the event the equipment is not available, the contractor may request JPL to loan the appropriate equipment for the duration of the test.

8.0 LABORATORY STANDARDS

Piece parts known as Laboratory Standards shall be obtained by the contractor and used to check out each new circuit and test each setup before using that circuit or setup on screening samples. The Laboratory Standards shall be devices of the same type as the screening samples (if possible) or ones which are of the same generic type, such as operational amplifiers, of which several types can be measured with the same test circuit. Therefore, only one type of operational amplifier Laboratory Standard is needed, with the exception of the LM108, HA2700, and LM124, where an identical Laboratory Standard must be used.

Accurate measurements of all applicable electrical parameters shall be made on the Laboratory Standards and the values retained so that the contractor's radiation test setup can be checked out prior to each radiation test for performance and accuracy.

9.0 TRAVELER AND SIGN-OFF SHEET

A traveler form will accompany each group of parts of the same type and of the same lot to be tested at one time. The purpose of the traveler is to completely indentify the parts and to require sign-off by the contractor's test engineer for each major step in the procedure. A sample of the traveler is shown in Figure C-1.

A key part of the procedure is the Joint Sign-Off Sheet (see Figure C-2) where both JPL and the contractor agree on the circuit(s) to be used for the RTR, with each traveler. A joint sign-off sheet must be completed for each new or revised RTR before testing is initiated. RTR's which have been used in prior tests will not require a Joint Sign-Off Sheet.

10.0 RADIATION TEST REQUIREMENTS

A Radiation Test Requirements (RTR) form governs each screen test on Voyager piece parts. The part identification, radiation levels, and bias conditions during exposure are given on page 1 of the RTR; the test parameters and conditions to be imposed before and after radiation exposures are shown on Page 2 of the RTR. Most tests are to be made <u>in situ</u> as defined on Page 2. A sample RTR is shown as Figure C-3.

11.0 TEST PROCEDURES

The test procedure as described below is a general plan, and it is anticipated that minor deviations may occur. No deviation in procedure shall occur without the knowledge and approval of the JPL Technical Contract Manager or his designated alternate. Each group of parts of the same type and the same lot number is considered as a separate independent test, even though several part types or groups

Device Type:______________ Mfg.:______________________ Pkg. Type:________________

Lot Number:_______________ Quantity:_________________ Log No:___________________

Diff. Run No:_____________ S/N's:____________________ RTR No:_______ Rev._________

Trace No:________________ ________________________ Circuit No:________________

Date Code:_______________ Test Type: Dyn ☐ Co 60 ☐ Reirradiate: Yes ☐ No ☐

Other Ident. No's:_____________________________________

ACTIONS	Initials	Date

SIGN-OFF LIST FOR NEW/REVISED RTR's

1. Contractor receives RTR.
2. Contractor responds to JPL with critique of RTR.
3. Contractor sends proposed test circuit schematic to JPL.
4. JPL approves proposed test schematic with sign-off.
5. Contractor signs approved test circuit for concurrence.
6. Contractor builds test fixture and obtains test equipment.
7. Contractor checks fixture and test set-up using lab standard devices.
8. JOINT SIGN-OFF SHEET signed.

FOR OLD RTR

Record Previous Test Date:___________ RTR No.____________ Rev.________ Circuit #_________

SIGN-OFF LIST FOR DEVICE TESTING — Initials — Date

1. Contractor receives devices with RTR and Traveler.
2. Contractor measures test devices on test system at HAC.
3. Time scheduled at radiation source.
4. Priority of testing established by JPL.
5. Contractor sets up at test site specified.
6. Contractor carries out test per specified RTR and circuit.
7. Contractor returns test data and test devices to JPL.

Figure C-1. JPL Lot Screening Radiation Test Traveler and Sign-Off Sheet

Log No. __________
Device Type __________
Circuit No. __________
RTR No. __________

JPL

Circuit diagram approved.

Proceed with test after carrying out action items 1 through 7.

Approval Signature Date

TESTING CONTRACTOR

RTR approved and executed.

Devices tested on circuit board.

Approval Signature Date

Figure C-2. Joint Circuit Sign-Off Sheet

Date 9/5/75

RADIATION TEST REQUIREMENTS

Device Type HA 2700 (in situ) SN 11 Rev. 4

Manufacturer Harris

Lot No.______ Date Code ______

No. of Devices Supplied ______

No. of Devices to be Tested ______

Package

Type	No. of Leads
Metal can TO-99	8
Flatpack TO-116	14
Flatpack TO-91	10

Radiation Cond.

Facility: Dynamitron

Energy: 2.5 VeV

Levels

Fluence: 5×10^{11} 1.25×10^{12} 2.5×10^{12} 5×10^{12} e/cm

Flux: 5×10^{8} 7.5×10^{8} 1.25×10^{9} 2.5×10^{9} e/cm sec

Bias Cond. During Irradiation:

	Pin No.			Parameter	Voltage	Remarks	Bias Circuit
	Can						
	1	2	2	Offset Adj	Open		See Fig. C-4
	2	4	3	IN^-	100 K to ground		
	3	5	4	IN^+	100 K to ground		
AGS-1	4	7	5	V^-	-15 V		S_1 and S_2 open during irradiation
AGS-2	6	10	7	Out	10 KΩ to Summing Junction		
AGS-3	7	11	8	V^+	+15 V		
AGS-4	8	12	10	Offset Adj	Open		
		3,6		Guard	---		

Figure C-3. Sample RTR

RADIATION TEST REQUIREMENTS

(All measurements at 25°C in sequence)

G. Stakk	DRIRU	4048
E. Klippenstein	365	
S. Dodge	365	
R. Service	365	

Device Type: HA 2700

Preirradiation Spec. Limits:

V_{OS} <3mV, I_{OS} <10nA, I_B <20nA

JPL Contact:

Name	Subsystem	Phone
H. Coe	HYBIC	
C. Coppock	UVS	
F. Mazzocco	PPS	
V. Albrecht	MDS	
M. Woncik	RFS	
H. Mertz	PLS	
M. Agabra	PWS	
W. Harris	MDS	
T. C. Clark	ECS	

Measurement Conditions:

No.	In Situ Yes	In Situ No	Parameter	Test Conditions	Remark and Circuit
1	X		input offset voltage		
2	X		input offset current		
3	X		input bias current		

Figure C-3. Sample RTR (Continuation 1)

may be done in series. The procedure will take one group of parts through a test sequence in chronological order.

11.1 Parts are supplied by JPL to the contractor along with a traveler and RTR.

11.2 The contractor examines the RTR within 24 hours of receipt of errors or technical questions. If there are any, contractor personnel phone the JPL Technical Contract Manager or his designated alternate for discussion and resolution.

11.3 The contractor examines the test devices supplied for any problems in testing. If there are any, contractor personnel contact JPL for resolution.

11.4 The contractor prepares circuit drawings showing bias during radiation and measurement circuits. Switches in the circuit will have the conditions of use designated. The circuit drawing is returned to JPL for concurrence within 3 days after RTR receipt.

11.5 When a final version of the circuit is agreed to by JPL and the contractor, the circuit drawing is signed by each, a circuit number is assigned to the drawing, and one copy is retained by each. Future tests using the same circuit are referenced by circuit number.

11.6 The contractor builds test fixtures and obtains test equipment to carry out the required biasing and tests.

11.7 The contractor checks out the test fixture and test setup with Laboratory Standard parts (see Section 8 of this Appendix) within 5 days of receipt of the RTR. Measured values shall agree to within 10% of established values.

11.8 The contractor checks out the test devices on the contractor's radiation test system. If devices do not meet JPL specification or manufacturers' minimum-maximum, the contractor shall contact JPL for resolution. For transistors, use the lowest current dissipation operation values to obtain comparable measurement.

11.9 The Joint Sign-Off Sheet shall be obtained before proceeding with a radiation test. This form is initiated by JPL after agreement that the circuit is satisfactory and the correct RTR is being used.

11.10 JPL schedules time on the Dynamitron for the test. For cobalt 60 tests, the contractor sets the schedule. JPL sets priorities of the various tests to be done in the test series.

11.11 The contractor moves equipment to the test site and sets up in preparation for test. The contractor also checks with JPL to assure that RTR's to be used are still valid.

11.12 The contractor checks out the test setup with Laboratory Standard devices and records data. If previously measured parameter values do not agree within 10%, the contractor shall not proceed with the test, but will contact the JPL Technical Contract Manager or his designated alternate for resolution.

11.13 The contractor carries out the test according to the RTR. Any anomalies during test shall be recorded on the data sheet or on a separate page attached to the data. Data-taking must be completed within 5-15 minutes after the radiation exposure for _in situ_ measurements. For non-_in situ_ measurements, see Section 12.

11.14 The contractor repeats the Laboratory Standard Measurements and records data.

11.15 The contractor calculates data into required parameter values and reproduces a copy of the original data, parameter values calculated, the Joint Sign-off Sheet, the circuit schematic, the traveler, and a _separate anomalies sheet_ (if any) for JPL.

11.16 The data package copy is given to JPL as soon as possible, but within 24 hours of completion of data acquisition.

11.17 The contractor keeps the original data and related information filed for future reference.

11.18 The contractor processes the data through the Lot Screen computer program and provides a copy of the reduced, final printout to JPL within one week. The acceptance criteria given in Table C-1 shall be used.

12.0 TEST PROCEDURE FOR NON-_IN SITU_ TESTING

There are three modes of non-_in situ_ testing which shall be required in Lot Screening of Voyager piece parts:

Table C-1. Acceptance Criteria for Irradiated Integrated Circuits Subject to Screening

Device Type	Parameter	Lot Screen: RTR	Lot Screen: Accept Spec. All fluences	IRAN Reirradiate: RTR	IRAN Reirradiate: Acceptance Specification $2.5 \times 10^{12} e/cm^2$	IRAN Reirradiate: Acceptance Specification $5 \times 10^{12} e/cm^2$
DG129	I_S (off)			5E	<30nA	<30nA
DG133	I_S (off)			1E	<30nA	<30nA
DG141	I_S (off)			2E	<60nA	<60nA
HA2520	ΔI_{OS}	8	<40nA	8E	<40 5nA	<46nA
	ΔV_{OS}		<20mV		<17 2mV	<9.3mV
	ΔI_B		<1 A		<442nA	<839nA
	A_{OL}, 2mA	8B	<2000		>4680	>1860
HA2600	V_{OS}	9	<12mV			
	I_B		<20nA			
	I_{OS}		<60nA			
	A_{OL}, 2mA	9B	>7,100			
HA2620	V_{OS}	10	<5mV			
	I_{OS}		<150nA			
	I_B		<100nA			
HA2700(can)	V_{OS}	11	<10mV	11E	<3mV	<3.5mV
	ΔV_{OS}		<5mV		<1.9mV	<4.4mV
	I_{OS}		<30nA			
	ΔI_{OS}		<10nA		<2.7nA	<2.2nA
	ΔI_B		<40nA			
HA2700(FP)	ΔV_{OS}	11	<15mV			
	ΔI_{OS}		<10nA			
	ΔI_B		<40nA			
LM101A	ΔV_{OS}			12E	<3mV	<10mV
	ΔI_{OS}				<6nA	<15nA
	ΔI_B				<70nA	<120nA
LM102 Hard	ΔV_{OS}	13	<5mV			
	ΔI_B		<10nA			
LM105	Δ Output Reg.	17	<25mV			
	Δ Line Reg. V_{IN}-8.5V		<25mV			
	Δ Line Reg V_{IN}-40V		<25mV			
LM108 Hard	ΔV_{OS}	14	<0.5mV			
	ΔI_{OS}		<0.4nA			
	ΔI_B		<6nA			
	A_{OL}	14B	>45K			
LM111	V_{OS}			15E	<4 7mV	<6.4mV
	I_{OS}				<223nA	<313nA
	I_B				<1 9 A	<1.9 A
LM124	ΔV_{OS}	7	<25mV			
	ΔI_{OS}		<100nA			
	ΔI_B		<1µA			
	I_{SINK}, 5K load		>0.84mA			
	I_{SOURCE}, 5K load		>250µA			

(1) The HAC Tak-box is used on site to test devices under unsaturated conditions, where pulse testing is required to prevent annealing of the radiation-induced effects caused by high power dissipation. Other testing apparatus can be brought to the test site for on-site but non-*in situ* measurements. No change in procedure is required from that described in Section 11 other than the delay required for radiation source shut down and the time for the non-*in situ* tests.

(2) The second type of non-*in situ* test which shall be required is when the parameter measurements are done off-site by other than a HAC engineer. In this case, HAC personnel shall accompany the parts to ensure proper techniques are used to prevent annealing of the radiation effects and that the parts are moved expeditiously to and from the measurement site. Measurements shall be initiated no later than 10 minutes after the end of the radiation exposure. Scheduling arrangements shall be made by the HAC engineer directly with the personnel making measurements. The procedure should be similar to that described in 3 below.

(3) Devices requiring pulse-testing in the saturated mode require use of the JPL Fairchild 500 (FC 500) or the Lorlin Impact 100, which require off-site measurements. For devices requiring such measurements, the following procedure shall be followed:

(a) The contractor determines the non-in situ measurement requirement from the RTR.

(b) The contractor contacts the cognizant JPL Parts Test Engineer for the FC 500 or Lorlin at JPL 3 to 5 days in advance of the scheduled test date for agreement to use the tester and to schedule an operator's time for doing the measurements.

(c) The contractor supplies to the JPL Parts Test Engineer, at least 24 hours in advance of the test time, RTR documents detailing the test conditions. The contractor also supplies the test parts for preirradiation measurements and obtains a Test Condition Sheet from the operator.

(d) At least one control device shall be measured along with the test parts measurements for each set of measurements.

(e) On the morning of the test, the contractor shall confirm the detailed schedule with the Parts Test Engineer.

(f) The contractor carries out the series of radiation exposures on the test devices, hand-carrying the devices to the parts test laboratory after each exposure for parameter measurements. Measurements shall be started no later than 10 minutes after the end of the radiation exposure.

(g) Contractor personnel remain at the parts test site to observe the measurements and note any anomalies.

(h) The contractor shall check data for inconsistencies (if any), report the details, and remeasure.

All other procedures are the same as given in Section 11.

13.0 GENERAL PROCEDURE FOR PARTS TESTING: DATA IDENTIFICATION AND RECORDING

Many groups of parts are being tested in this program which are of the same part type, differing only in the details of processing at the manufacturer's. The differences are known to only a limited number of people and are, at times, proprietary. Therefore, it is extremely important to mark the data sheets to fully identify each device tested, giving all numbers which can be determined from the device package and the accompanying paper work.

Each test and test data are further identified with the date of the test and the run number used at the test site. The run number is to be used by the radiation source operator and should be a unique number. Contractor personnel are responsible for assigning the run number.

Actual irradiation levels are to be recorded on the data sheet, as opposed to the RTR required levels.

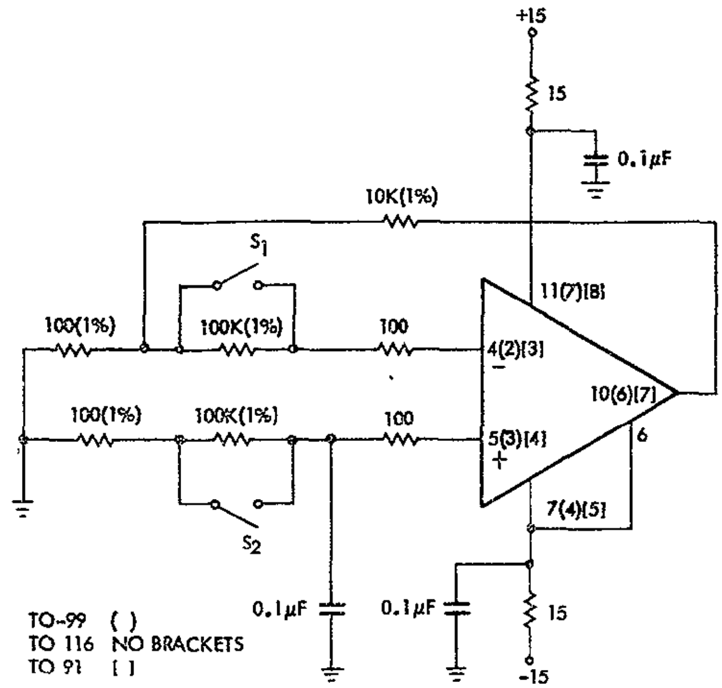

Figure C-4. Test Bias Circuit

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APPENDIX D

BOEING *IN SITU* TEST FIXTURE

DESCRIPTION

The Boeing Company constructed a test fixture to enable measurements of the electrical parameters of integrated circuits to be made *in situ*, that is, in the radiation exposure area but with the radiation source turned off. This allows measurements without the necessity of personnel entering the exposure area. To minimize the number of cables which are required between the exposure and measurement areas, remote switching between groups of six devices of a given type is employed. The switches are open-frame reed relay types which are compact and have very low leakage currents. Low-noise coaxial cable is used for current measurements. A preliminary experiment was performed which demonstrated that this cable is adequate for leakage currents as low as 10 pA in the experimental area.

An example of the measurement circuitry of this test fixture is shown in Figure D-1 for an analog switch. The required measurements are $r_{DS}(on)$, output switching waveform, and three leakage currents. The power supply and input connections are not included in this schematic. Relays K_D, K_S and K_A are groups of six relays which are connected to six different test devices and can be switched remotely. The relays are shown in the normal position during irradiation.

The switching response can be measured by connecting the line driver to the appropriate device with K_A, using an appropriate switching waveform from a pulse generator at the input of the device. All six units can be driven in parallel from the same pulse source. The line driver is used to eliminate the effect of the cable capacitance on the output of the device, and a terminated cable is used on the line driver output. An oscilloscope is used to record the switching response of the device under test. The pulse generator and line driver are connected to coaxial cables, terminated in their characteristic impedance.

The *on* resistance, $r_{DS}(on)$, is measured by closing K_A and measuring the output voltage of the line driver with a digital voltmeter. The current for r_{DS} is determined by V_{DD} and the drain resistance.

The (drain, source) gate leakage current is measured by switching K_D and K_S, shorting the source and drain together with K_2 and measuring the leakage current with the electrometer at an applied voltage V_1. With the various combinations of K_1 and K_2 the leakage current of the source (drain) with the drain (source) at V_2 can be measured.

The relay switches were constructed on 1 x 6 matrix cards which can be plugged into a specific test card for a given device type. This eliminated the necessity of hard wiring relays to each test card. Appropriate test cards were designed for other device types, such as operational amplifiers and transistors which utilize the same relay cards.

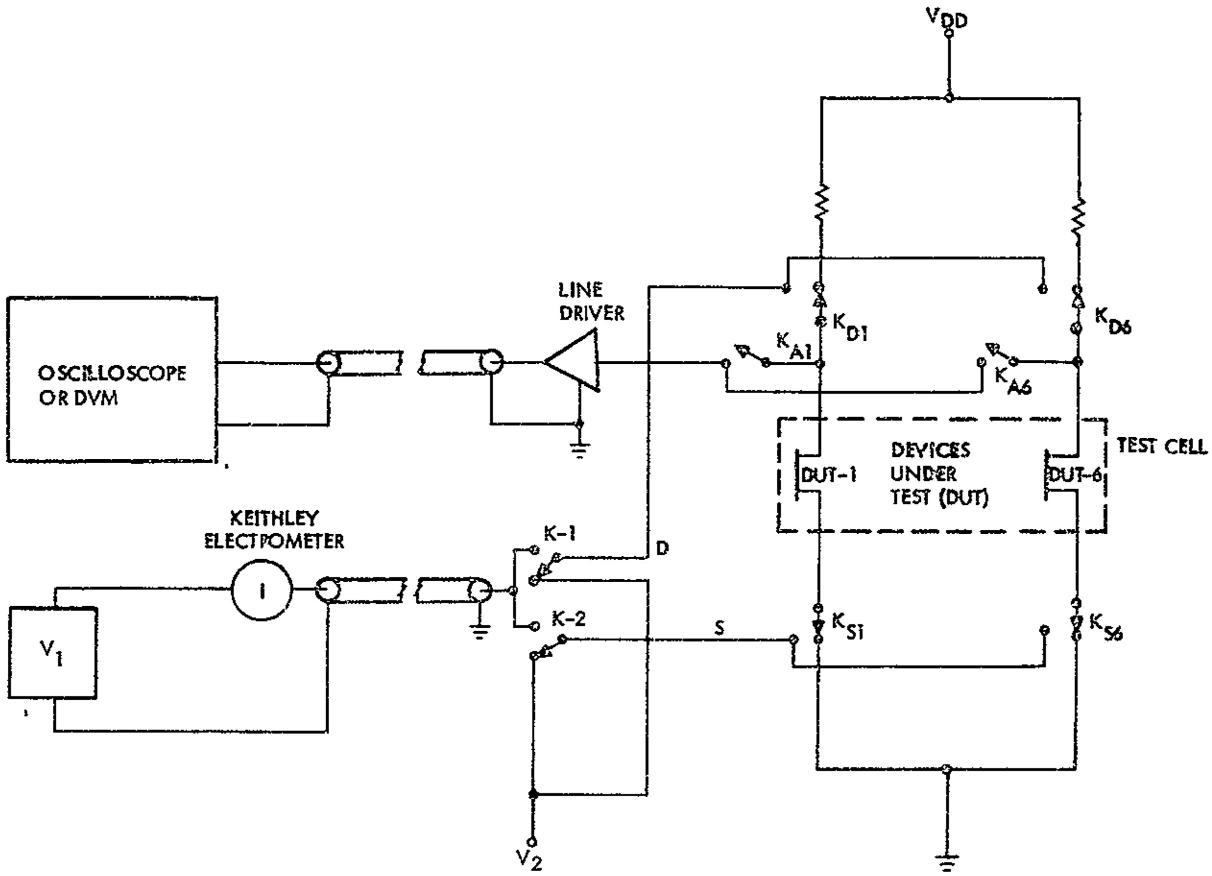

Figure D-1. Typical Measurement Circuit for Analog Switch, Integrated Circuits

For manual measurements, the minimum time for a single measurement is approximately 10 seconds. For 6 devices, with 4 measurements per device, this is approximately 250 seconds or 4 minutes. This does not include time required to change ranges. In addition, 30 seconds to 3 minutes is required to obtain stable readings of low leakage currents because of cable capacitance charging and instrument response times. When all of these factors are considered, measurement times from 5 to 15 minutes were required between radiation levels, depending on the types of measurements required.

Because of the complexity of testing several devices, it is necessary to fabricate special test cards and required lengthy preparation and checkout times. *In situ* measurements have the disadvantage that no control devices can be used. This difficulty was largely eliminated by careful preirradiation checkout of the setup.

The same general approach was also used to test operational amplifiers and comparators, although the details of the tests are not included in this Appendix. A special null amplifier was constructed and built into the text box in order to make measurements of the input parameters of differential comparators. The null amplifier could be switched in and out of the test fixture by the existing reed relay cards. The test fixture permitted testing up to 6 devices of a given type during each irradiation sequence.

PHYSICAL LAYOUT OF THE IN-SITU IC TEST FIXTURE

The physical layout of the remote test fixture is shown in Figures D-2 through D-4. Basically, it consists of eight modules of six relays each, which allow automatic sequencing of six different connections. Within each module, the six relays can be held either on or off during a test sequence or they can be held on and switched off individually by the clock. These features are shown in the block diagram form in Figure D-5. The overall test system is shown in block diagram form in Figure D-6.

IC TEST FIXTURE AND PROGRAMMING PROCEDURE

The physical layout of the test fixture is described in the preceding section. The procedure for programming a given part test is as follows:

(1) The Parts and Test Specifications are received.

(2) A test board is designed to accommodate the package configuration with the test fixture.

(3) Each test condition is then drawn schematically.

(4) The test conditions are then reviewed for mutual compatability and then the overall test fixture circuit is drawn.

(5) A table is then made listing all of the interconnects to be made on the patch terminals in the test fixture to implement the overall test schematic. The relay conditions for each test are tabulated along with pin voltage conditions to implement each test.

(6) These diagrams and tables are then used to hook up, or program, the test with hardware.

(7) An initial check of pin voltages is made at each device socket for each test, to assure that no catastrophic electrical conditions have occurred.

(8) The parts are tested on a Textronix Curve Tracer, or bench fixture, prior to insertion into the test fixture. This verifies proper initial operation.

(9) Having established that the desired electrical conditions are satisfied, one device is inserted for checkout, then the other devices are inserted and the test begun.

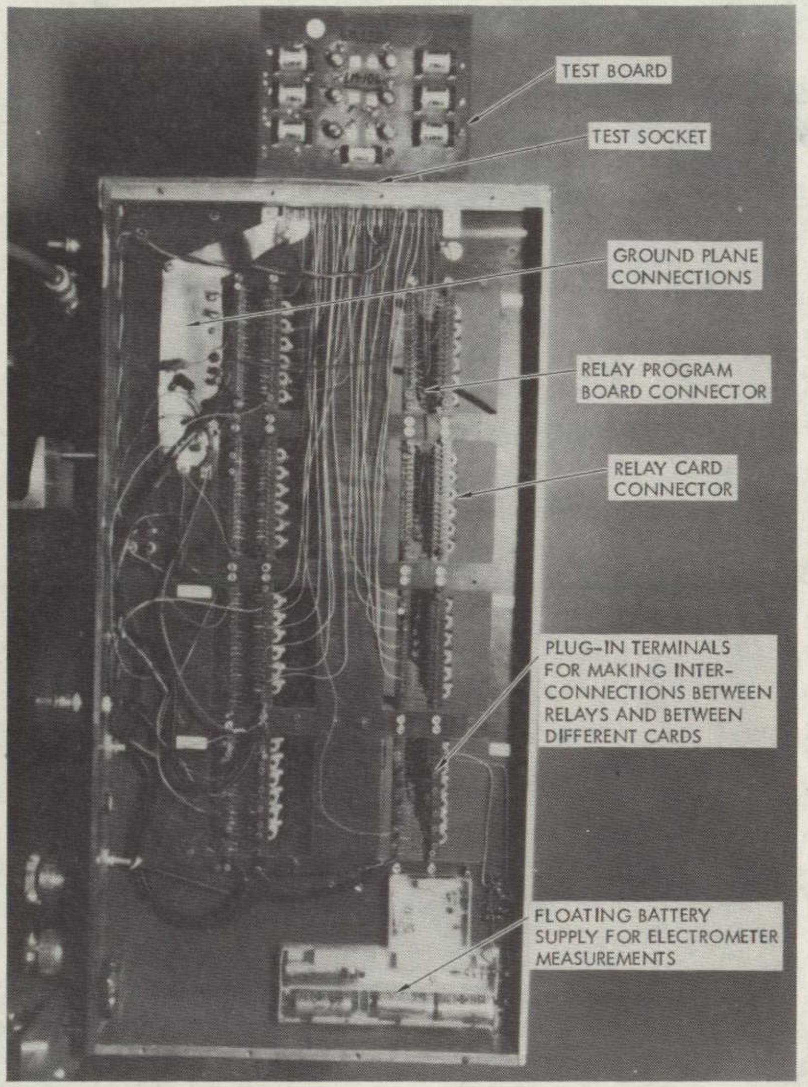

Figure D-2. Front View of the Test Fixture With 1.27 cm (1/2 in.) Aluminum Shield Removed. This View Shows the Arrangement of the Relay Cards and the Plug-In Terminals Which Permits the Programming of a Given Test

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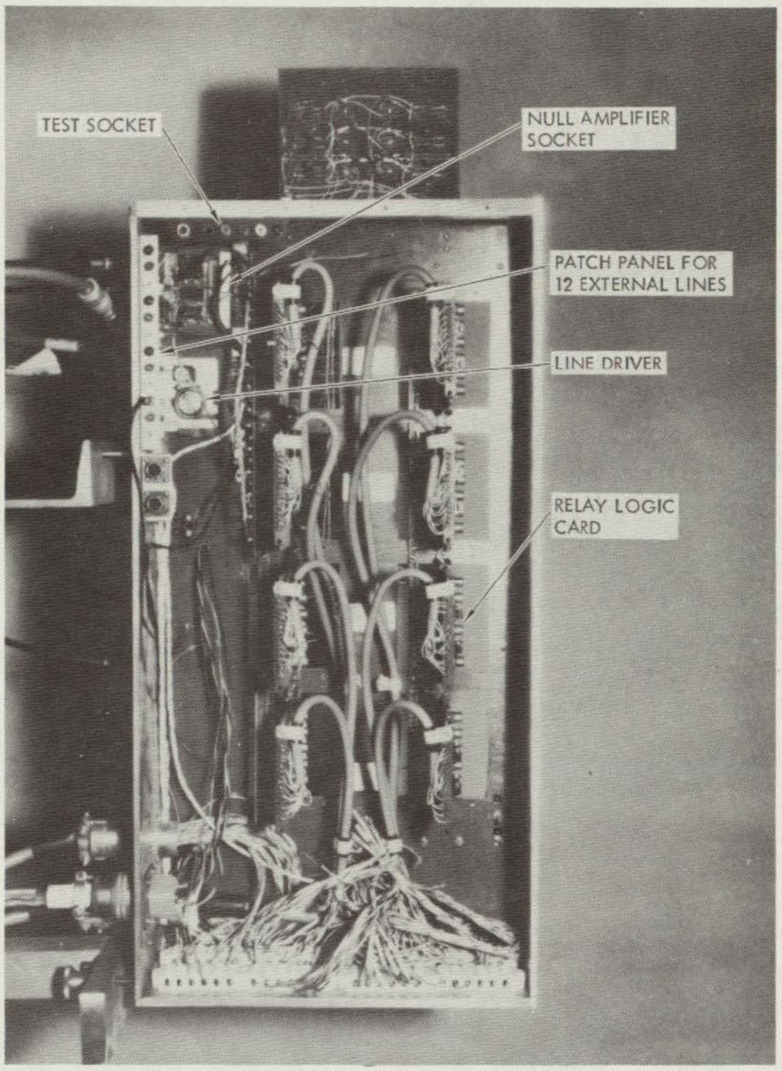

Figure D-3. Rear View of Test Fixture, Showing the Arrangement of Relay Logic, Line Driver, Null Amplifier, And Other Elements

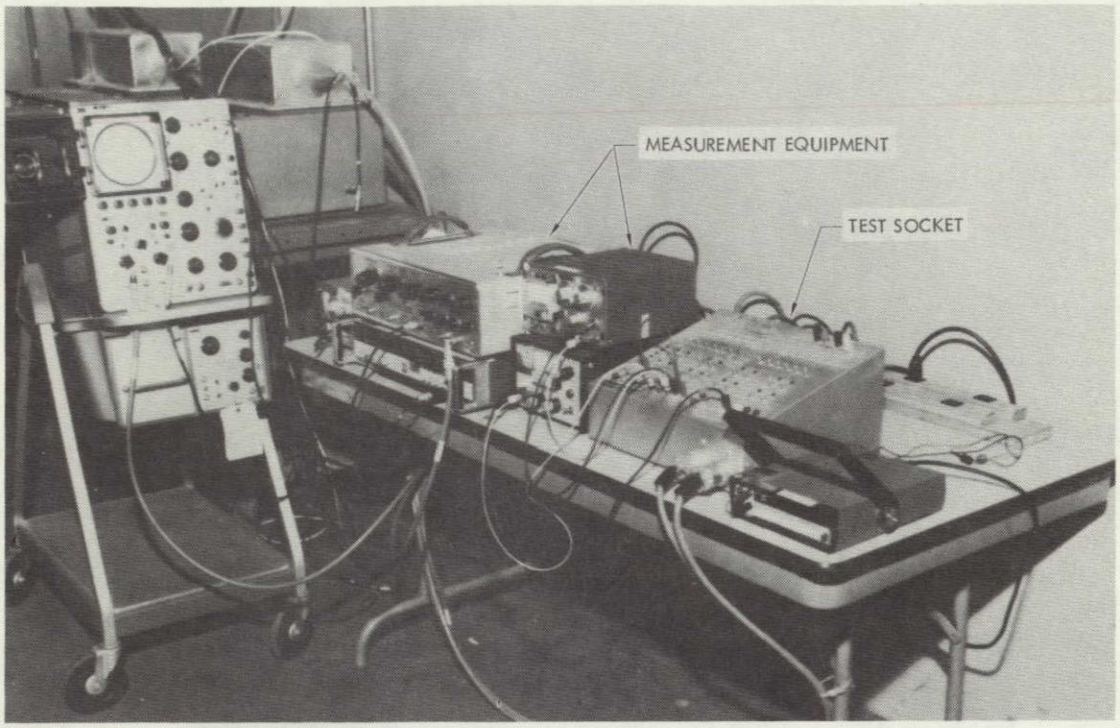

Figure D-4. Interface Panel. This Panel Allows the Relay Logic to be Controlled by the ACE Machine or To Be Controlled Manually by the Switches. Twelve External Lines Are Available for Sending Signal Lines Directly to the Test Fixture or for Patching Into the ACE Machine

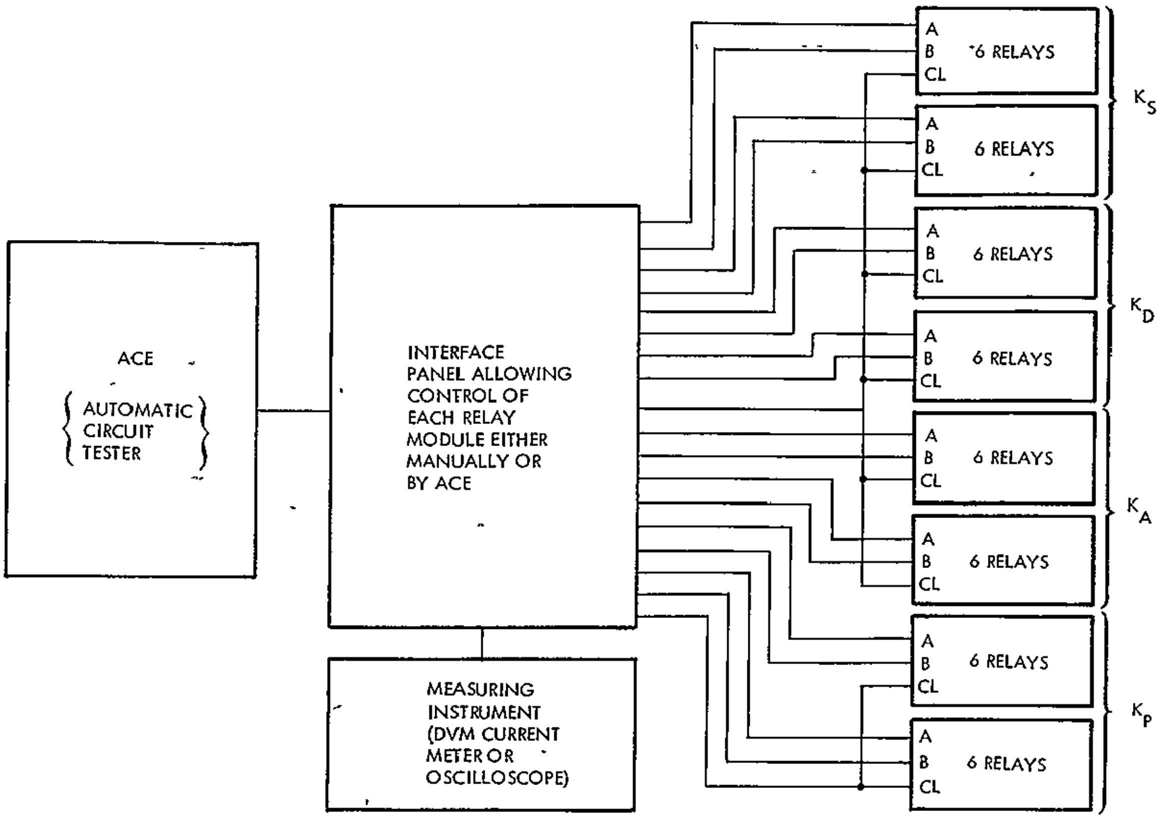

Figure D-6. Block Diagram of Overall Test System

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APPENDIX E

IRRADIATE-ANNEAL (IRAN) SCREENING DOCUMENTS

PART I

TEST PROCEDURE FOR IRRADIATION-ANNEAL (IRAN) SCREENING PROGRAM FOR VOYAGER SEMICONDUCTOR DEVICES

1.0 SCOPE

This Test Procedure (TP) presents the procedures, instrumentation, and methods of measurement required for the performance of IRAN screening of Jet Propulsion Laboratory (JPL) furnished semiconductor parts. The IRAN testing of the semiconductors shall be performed in accordance with the requirements of Contract Number 954269. A flow diagram of the program is shown in Figure E-1.

The semiconductor devices shall be screened using a gamma ray radiation source (cobalt 60) which produces surface ionization effects. Due to the nature of surface ionization effects, which exhibit a rapid initial partial annealing, the electrical parameter tests shall be performed *in situ* within 15 minutes after irradiation to the required dose level. For open loop gain measurements the devices shall be removed from the test system, and tested on the bench within one hour after parts irradiation.

2.0 TEST SAMPLE NOMENCLATURE

The test samples to be evaluated are identified in Table E-1 as operational amplifier, voltage comparator, analog switch microcircuit devices and JFETs.

Table E-1. JPL-Furnished Part Types for IRAN Test

Item	Device Package	Type	Quality Range	Manufacturer
1	HA2-2700	(TO-99)	629-1048	Harris
2	HA9-2700	(FP)	368-610	Harris
3	LM101AH	(TO-99)	397-400	National
4	LM101AF	(FP)	230-375	National
5	LM111H	(TO-99)	278-300	National
6	LM111F	(FP)	264-285	National
7	DG129	(FP)	84-119	Siliconix
8	DG133	(FP)	273-350	Siliconix
9	DG141	(FP)	60-100	Siliconix
10	2N5556	(TO-72)	80	Motorola
11	2N5520	(TO-71)	10	Siliconix
12	2N5196	(TO-71)	77	Siliconix
13	2N4856	(TO-18)	220	Siliconix

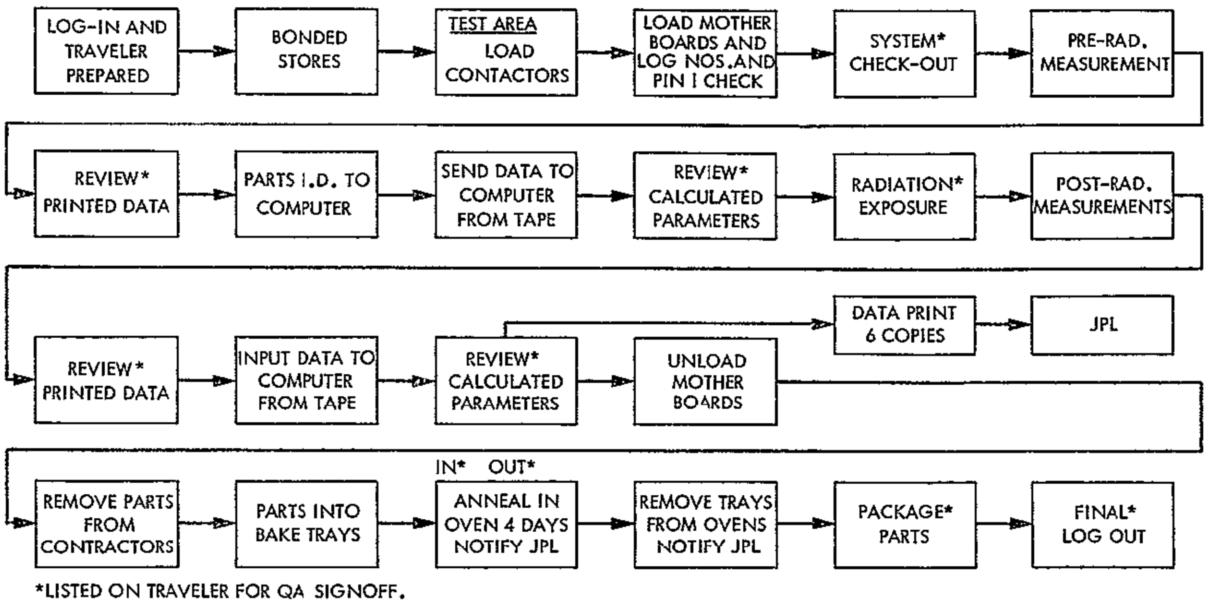

Figure E-1. IRAN Screening Program Procedure

3.0 SECURITY CLASSIFICATION

The test samples are unclassified.

4.0 APPLICABLE DOCUMENTS

The following JPL documents form a part of this test procedure to the extent specified herein.

A. "Radiation Screen-Anneal Services," Contract Number 954269. (JPL internal document).

B. EP 595977 Rev. A, dated 30 September 1971, JPL Procedure, "Hi-Rel Program for Microcircuits," Paragraph 7 (JPL internal document).

C. ZPP2073-GEN Rev. H, "Screening Inspection of Electronic Parts, General Inspection For" (JPL internal document).

5.0 TEST REQUIREMENTS

Table E-2 shows individual part types and test parameters used in testing. The test devices will be subjected to electrical tests before irradiation; parts which fail to meet the acceptance limits listed in the document referenced in Table E-2 will be identified. After irradiation, parts which fail to meet the IRAN acceptance specifications as given on each Radiation Test Requirement (RTR) document shall be identified on the final test data sheet. Test parts shall be annealed after irradiation at 150°C ± 3°C for ≥ 96 hours, after which time they shall be packaged and JPL notified for pickup.

Table E-2. IRAN Parameter Testing

Item	Part Type No.	Test Parameters	Ref.
1	LM101	V_{OS} = Input offset voltage	ST11149
		I_{OS} = Input offset current	
		I_B = Input bias current	
2	JFETs	I_{GSS}	Mfg. Spec.
3	HA-2700	V_{OS} = Input offset voltage	ST11148
		I_{OS} = Input offset current	
		I_B = Input bias current	
4			
5	LM111	V_{OS} = Input offset	ST11149
		I_{OS} = Input offset current	
		I_B = Input bias current	
6	DG129 DG133 DG141	$I_{S(OFF)}$ = Drain - Source current in OFF condition	ST11146

6.0 PERSONNEL AND RESPONSIBILITIES

The following personnel shall be present as required during the performance and implementation of IRAN testing, and shall have the stated responsibilities.

A. Radiation Effects Test Engineer (RETE)

The RETE, functioning as Test Conductor, has the overall responsibility for proper test performance and implementation of the requirements of this Test Procedure.

B. Radiation Effects Test Technician (RETT)

The RETT shall be assigned to be responsible for setting up the various instrumentation and test configuration, logging in parts and maintaining the parts test record.

C. Quality Assurance Representative

A JPL QA representative shall monitor the performance of IRAN in accordance with the provisions of this Test Procedure.

7.0 GAMMA-RAY FACILITY

The facility to be used in this program is the Hughes Aircraft 50,000 curie source located in Fullerton, California. This source is a Gammabeam Model 650, manufactured by Atomic Energy of Canada, Ltd.

8.0 DOSIMETRY

The cobalt 60 source shall be calibrated and the exposure positions mapped prior to starting the IRAN program, by use of LiF thermoluminescent dosimeters. The source calibration shall be checked analytically on a monthly basis using the known decay characteristics of cobalt 60.

9.0 TEST EQUIPMENT

The test equipment presented in Table E-3, or the acceptable equivalents (as determined by the responsible RETE, with JPL concurrence), shall be required for use during the performance of the tests covered by this procedure. The test equipment acceptability for performance of these tests shall be determined on the basis of part performance requirements and parameter measurements. A test equipment log shall be maintained during the performance of the IRAN tests which shall include the type of equipment (nomenclature), part or model number, serial number, manufacturer, calibration date and calibration due date.

Table E-3. Equipment Required for IRAN Test Performance

Item	Quantity	Equipment Description	Model	Manufacturer
1	2	Digital Voltmeter	5800	DANA
2	2	Thermal Chamber	IPS-24	Tabai
3	1	Temperature Potentiometer	Catalog # 8692	Leeds-Northrup
4	2	Data Terminal	WU 300	WUDSC
5	2	Digital Recorder	5050B	Hewlett-Packard
6	1	Automatic Data Acquisition Test Station	ATS-1	HACRE
7	1	Data Set	103F	Bell Sys.

It shall be the responsibility of the test technician to ensure that all calibrated equipment is in current calibration at the time of their usage.

10.0 TEST SAMPLE OPERATION

The test devices that are listed in Table E-1 shall be irradiated under the bias conditions specified in the RTR's. The operating conditions for irradiation are defined in the individual RTR's. The electrical parameters listed in Table E-2 shall be measured _in situ_. In order to perform the parameter measurements, discrete components shall be switched in and out of the required test circuits while the devices are located in the cobalt 60 source. This shall be accomplished by stepper switches which are controlled from the automatic Test Console panel. The actual mechanics of the test operation are described in Part II, the Test Station Operational Procedure.

11.0 CIRCUIT LOADS

During IRAN testing the device outputs shall be nominally loaded as specified for each individual part type. The operational amplifiers are set up for a nominal gain of 100 during parameter measurements and irradiations. During irradiation the voltage comparator shall be terminated into 5.0 kilohms and during the measurements it shall be additionally terminated into a buffer input.

12.0 TEST PROCEDURES

All test specimens received at the HAC-Fullerton facility shall be placed in bonded stores while not being tested or annealed. The Master Log and Test Traveler shall be maintained during the test operation until the IRAN effort is completed and JPL notified for parts pickup. A typical Master Log that shall be used during the IRAN tests is shown in Figure E-2, and a typical Test Traveler in Figure E-3. The test operation required to perform electrical parameter measurements is described in the Test Station Operational Procedure (Part II). During the performance of electrical measurements, one device will be designated as a control unit which shall accompany each test lot and be measured during the electrical measurements. This device shall not be irradiated or baked, but shall be used for verification of test results. During the tests the control unit shall be located at the Test Console and not in the irradiation test fixture located in the cobalt 60 chamber. Upon completion of initial electrical measurement, the test devices shall be checked for compliance of measured parameter values to the limits given for each individual part as listed in documents referenced in Table E-2. The test devices shall then be irradiated at the desired dose rate, to the desired dose level, after which the established electrical parameters shall again be measured <u>in situ</u>. Where applicable the test devices shall be placed on trays and baked in an oven at $150^{\circ}C \pm 3^{\circ}C$ for ≥ 96 hours, after which the devices shall be repackaged in the original containers, and JPL notified for pickup.

13.0 TEST DATA PRESENTATION

The test data package for the IRAN test effort shall consist of 6 copies each of the raw test (Figure E-4), final test data (Figure E-5) and, if requested by JPL, Data Terminal printout. Figure E-6 shows the Data Sheet to be used to record the device serial number vs socket number. Each Data Sheet will be signed by the RETE and stamped by the JPL QA representative, but shall not form a part of the data package.

14.0 QUALITY ASSURANCE

The test device handling, which is specified on the Test Traveler, during the IRAN operation is described in a step-by-step fashion in Part III. Each Test Traveler shall be signed by the responsible test personnel and the JPL QA representative at each designated step. A Master Log (Figure E-2) shall be maintained. Cursory visual inspection by JPL QA personnel shall be performed as required at the HAC-Fullerton test facility.

Device Type	Mfg	Qty	Date Rec'd	JPL Shipper Number	Lot Number	Date Code	VIS Insp Date	Irrad Date	Anneal Start Date	Anneal Out Date	JPL Notified	JPL Pickup	Remarks

Figure E-2. Master Log of IRAN Parts

JPL-IRAN TRAVELER

Device Type: ______________ Lot No:______________ Traveler No.______________

Manufacturer:______________ Date Code:____________ Date/Run No.______________

Dose, Rad (Si): ___________ RTR No. _____Rev.____ Quantity _________________

Exposure Time (min). _____

Item No.	Operation	Date & Initial	Q.A. Appr.
1.	Receive & Log-in to Bonded Stores		
2.	Load Contactors		
3.	Load Mother Boards (Log Socket No. vs.		
	Device S/N) pin 1 check		
4.	System Checkout		
5.	Pre-Irradiation Measurements		
6.	Review Printer Data		
7.	Input Parts I.D. to Computer		
8.	Input Test Data to Computer (Punch Tape)		
9.	Review Computer Output & Retest as Required		
10.	Expose Devices Rad(Si)/sec. Rad(Si)		
11.	Post-Irradiation Measurements		
12.	Review Printer Data		
13.	Input Test Data to Computer (Punch Tape)		
14.	Review Computer Output & Retest as Required		
15.	Request 6 Copies of Data (4 to JPL, 1 HAC,		
	Item 25)		
16.	Unload Mother Boards		
17.	Remove Parts from Contactors		
18.	Place Parts in Annealing Trays		
19.	Log Parts into Anneal & notify JPL		
20.	Anneal		
21.	Log Parts out of Anneal Total Anneal		
	Time hrs.		
22.	Remove Parts from Oven & Notify JPL		
23.	Repackage Parts		
24.	Log out Parts		
25.	Release Parts & One Copy of Data, one copy		
	computer printout to JPL		

NOTE: LINE OUT ALL NON-APPLICABLE LINE ITEMS

Figure E-3. JPL IRAN Test Traveler

DEVICE TYPE: LM101AF
MANUFACTURER: NSC
LOT NUMBER :10158
DATE CODE: 7532

TRAVELER NO: 64

DATE-RUN: 12-15-75-3
EXPOSURE: 125KRAD(SI)
RATE: 50RAD(SI)-SEC
FACILITY: HAC-FUL

RTR NO: 12C - REVISION: 5

	ACCEPT CRITERIA		
PARAM.	PRE-RAD	POST-RAD	DELTA
VOS(V)<	.200E-02	.000E+00	.700E-03
IOS(A)<	.100E-07	.000E+00	.250E-08
IB(A) <	.750E-07	.000E+00	.600E-07

SKT. NO.	LOT-DEV. S/N	PRE-IRRADIATION VALUES (VOLTS)				POST-IRRADIATION VALUES (VOLTS)			
		ESO	ESS	EOS	EOO	ESO	ESS	EOS	EOO
1	STD-555	- .5221	- .1195	+ .2416	- .1613	- .5218	- .1204	+ .2394	- .1624
2	10158-6672	- .5189	- .0719	+ .3679	- .0793	- .9714	+ .0132	+ .9954	+ .0113
3	10158-6673	- .2293	+ .0150	+ .2793	+ .0346	- .9731	+ .0469	+1.2247	+ .2043
4	10158-6675	- .2353	+ .0203	+ .2728	+ .0174	- .7939	+ .0941	+ .9403	+ .0522
5	10158-6678	- .3715	+ .0384	+ .4578	+ .0477	- .6178	+ .0915	+1.0259	+ .1165
6	10158-6679	- .4026	+ .0787	+ .5747	+ .0976	- .6537	+ .1977	+1.3032	+ .2567
7	10158-6683	- .3711	+ .0861	+ .5523	+ .0964	- .9137	+ .1664	+1.2844	+ .2040
8	10158-6685	- .1490	+ .0306	+ .2049	+ .0252	- .5185	+ .0563	+ .6427	+ .0618
9	10158-6686	- .5401	- .0686	+ .3934	- .0769	-1.0559	+ .0194	+1.1009	+ .0248
10	10158-6687	- .2414	- .0151	+ .2086	- .0173	- .5489	+ .0639	+ .6802	+ .0673
11	10158-6690	- .4656	- .0351	+ .3903	- .0409	- .9105	+ .0406	+ .9953	+ .0448
12	10158-6691	- .5919	- .1506	+ .2658	- .1753	-1.0358	- .0630	+ .8780	- .0949
13	10158-6692	- .1906	+ .0136	+ .2195	+ .0140	- .6075	+ .0342	+ .6869	+ .0452
14	10158-6693	- .1038	+ .0785	+ .2653	+ .0835	- .4560	+ .1064	+ .6857	+ .1235
15	10158-6700	- .4471	+ .0117	+ .4552	+ .0002	- .6571	+ .1121	+1.1394	+ .1262
16	10158-6702	- .3751	- .1045	+ .1636	- .1068	- .8191	- .0668	+ .6937	- .0583
17	10158-6703	- .2737	- .0792	+ .1101	- .0839	- .7235	- .0527	+ .6200	- .0443
18	10158-6705	- .4080	- .0578	+ .3030	- .0471	- .8301	+ .0063	+ .8308	+ .0536
19	10158-6706	- .2864	- .0327	+ .1822	- .0718	- .9542	- .0097	+ .8572	- .0844
20	10158-6707	- .4308	+ .0246	+ .5049	+ .0498	- .9473	+ .1378	+1.2401	+ .1950
21	10158-6710	- .4438	+ .0020	+ .4609	+ .0159	- .9908	+ .0681	+1.1760	+ .1173
22	10158-6715	- .3343	- .1326	+ .0598	- .1415	- .7687	- .0983	+ .5554	- .1139
23	10158-6716	- .2157	+ .0618	+ .3254	+ .0481	- .7039	+ .1152	+ .9374	+ .1165
24	10158-6721	- .1938	+ .1399	+ .5100	+ .1643	- .4041	+ .2247	+1.0642	+ .2378
25	10158-6722	- .3328	- .0616	+ .2122	- .0588	- .7815	- .0281	+ .7460	- .0072
26	STD-555	- .5221	- .1193	+ .2412	- .1616	- .5221	- .1201	+ .2400	- .1620

NOTE:
DEVICES ON SOCKETS 1 AND 26 ARE CONTROL DEVICES.

Figure E-4. Sample of Raw Test Data, JPL IRAN Program

DATE-RUN: 12-15-75-3

SKT. NO.	LOT-DEV. S/N	PARAMETER AND UNITS	PRE-IRRADIATION VALUES	POST-IRRADIATION VALUES	DELTA VALUE	DECISION
1	STD-555	VOS(MV)	- 1.195	- 1.204	- .009	
		IOS(NA)	+ 4.180	+ 4.200	+ .020	
		IB(NA)	+ 38.185	+ 38.060	- .125	
2	10158-6672	VOS(MV)	- .719	+ .132	+ .851	REJ(DEL)
		IOS(NA)	+ .740	+ .190	- .550	
		IB(NA)	+ 44.340	+ 98.340	+ 54.000	
3	10158-6673	VOS(MV)	+ .150	+ .469	+ .319	
		IOS(NA)	- 1.960	- 15.740	- 13.780	REJ(DEL)
		IB(NA)	+ 25.430	+109.890	+ 84.460	REJ(DEL)
4	10158-6675	VOS(MV)	+ .203	+ .941	+ .738	REJ(DEL)
		IOS(NA)	+ .290	+ 4.190	+ 3.900	REJ(DEL)
		IB(NA)	+ 25.405	+ 86.710	+ 61.305	REJ(DEL)
5	10158-6678	VOS(MV)	+ .384	+ .915	+ .531	
		IOS(NA)	- .930	- 2.500	- 1.570	
		IB(NA)	+ 41.465	+ 92.185	+ 50.720	
6	10158-6679	VOS(MV)	+ .787	+ 1.977	+ 1.190	REJ(DEL)
		IOS(NA)	- 1.890	- 5.900	- 4.010	REJ(DEL)
		IB(NA)	+ 49.065	+108.095	+ 59.030	
7	10158-6683	VOS(MV)	+ .861	+ 1.664	+ .803	REJ(DEL)
		IOS(NA)	- 1.030	- 3.760	- 2.730	REJ(DEL)
		IB(NA)	+ 46.220	+109.925	+ 63.705	REJ(DEL)
8	10158-6685	VOS(MV)	+ .306	+ .563	+ .257	
		IOS(NA)	+ .540	- .550	- 1.090	
		IB(NA)	+ 17.695	+ 58.060	+ 40.365	
9	10158-6686	VOS(MV)	- .686	+ .194	+ .880	REJ(DEL)
		IOS(NA)	+ .830	- .540	- 1.370	
		IB(NA)	+ 46.675	+107.840	+ 61.165	REJ(DEL)
10	10158-6687	VOS(MV)	- .151	+ .639	+ .790	REJ(DEL)
		IOS(NA)	+ .220	- .340	- .560	
		IB(NA)	+ 22.500	+ 61.455	+ 38.955	
11	10158-6690	VOS(MV)	- .351	+ .406	+ .757	REJ(DEL)
		IOS(NA)	+ .580	- .420	- 1.000	
		IB(NA)	+ 42.795	+ 95.290	+ 52.495	
12	10158-6691	VOS(MV)	- 1.506	- .630	+ .876	REJ(DEL)
		IOS(NA)	+ 2.470	+ 3.190	+ .720	
		IB(NA)	+ 42.865	+ 95.690	+ 52.805	

Figure E-5. Sample of Final Test Data, JPL IRAN Program

DATA SHEET

Device Socket No./Device Serial No.

Traveler No. ____________

Date/Run ____________
Device Type ____________
Manufacturer ____________
Lot Number ____________
Date Code ____________
Mother Board ____________
Adaptor ____________
Stepper ____________

Socket No.		Lot - S/N
1	STD	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		

		Lot - S/N
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

Figure E-6. Data Sheet, Device Socket No./Device Serial N

15.0 TEST FAILURES AND RETEST REQUIREMENTS

All anomalies shall be reported to the JPL Component Specialist by telephone, followed by a copy of the Hughes Avoid Verbal Orders, form 15CS, Sept. 72. The Radiation Effects Test Engineer and JPL Technical Monitor shall be notified within one working day when the test data indicates out-of-tolerance conditions, at which time consideration shall be given to evaluate the anomaly and establish conditions and requirements for re-testing.

PART II

TEST STATION OPERATIONAL PROCEDURE FOR IRRADIATION-ANNEAL

SECTION 1

SYSTEM SETUP

1.1 EQUIPMENT SETUP

1.1.1 Exposure Station

The exposure station consists of the equipment located in the exposure cell near the cobalt 60 gamma source. The equipment is to be set up as indicated below.

1.1.1.1 Switching System. The Switching System box is placed inside the screen enclosure which is located on the special support fixture.

1.1.1.2 Stepper Control. Place the Stepper Control box inside the screen enclosure.

1.1.1.3 Cable Assemblies. Perform the following:

(1) Connect cable assemblies No. 1 and No. 2 to J1 and J2 on the Switching System box.

(2) Connect the stepper control cable to the Stepper Control box.

(3) Route the cables to the data room for connection to the test station.

1.1.2 Test Station

The test station consists of an equipment cabinet located in the data room near, but shielded from, the exposure cell.

1.1.2.1 Connect the three cable assemblies from the exposure cell to the corresponding receptacles on the Test Console.

1.1.2.2 Connect the data processor cable assembly to the Radiation Analysis Data System chassis and route the cable to the data processing station.

1.1.3 Data Processing Station

This station consists of data acquisition and computer interface equipment.

1.1.3.1 Connect the cable assembly, from the test station, to the receptacle on the Remote head.

1.1.3.2 The cable from the Tape Module is to be connected to the Remote Head.

1.1.3.3 Connect the cable assembly between the Remote Head and the Data Set.

<u>NOTE</u>

Exercise extreme care in connecting all cable assemblies. JPL QA representative is to verify correct connector mating (ref. Part III, para. 4.0).

1.2 SYSTEM POWER

1.2.1 Test Station

1.2.1.1 <u>Test Console</u>. Perform the following:

(1) Position the Power switch in the OFF position.

(2) Place the Manual/Auto switch in the MANUAL position.

1.2.1.2 <u>Main Frame</u>. Place the Power switch on the equipment cabinet in the ON position.

1.2.1.3 <u>Digital Voltmeter</u>. Operate the Power switch to turn the DVM power ON.

1.2.1.4 <u>Radiation Analysis Data System</u>. Depress the Power switch lighting the power indicator.

1.2.1.5 <u>Ammeter</u>. Turn ammeter power switch ON.

1.2.2 Data Processing Station

1.2.2.1 Remote Head. Perform the following:

(1) Power. Verify that system power is ON as shown by the illuminated indicator.

(2) Console Select. Depress the Console Select button illuminating the indicator.

1.2.2.2 Tape Module. Perform the following:

(1) Power ON. Press the Power switch to turn module power ON.

(2) Printer ON. Depress the Printer switch, obtain "PRINTER" reading on the Tape Module readout.

(3) Term Data. Operate the Source switch to obtain "TERM DATA" on the module readout.

(4) Off Line. Press the Online switch to obtain a flashing "ON LINE" readout.

1.2.2.3 Data Terminal. Perform the following:

(1) Power ON. Operate the power switch located at the rear of the data terminal. Indicator lamps will illuminate on the front panel.

(2) On Line. Press the Line switch illuminating the line indicator.

(3) Ready. Depress the Ready switch lighting the indicator.

NOTE

Allow equipment to warm up for 15 minutes before proceeding to Section 2.

SECTION 2

SYSTEM CHECKOUT

2.1 TEST EQUIPMENT SETUP

Test equipment is to be set up as indicated below. Selection of equipment to be used in controlled by Table E-4.

NOTE

If the test equipment is already set up and continued screening does not require a change of stepper switches or if Table E-4 requires no diagnostic check go directly to Step 3.

2.1.1 Switching System

2.1.1.1 Stepper Switches. Two stepper switches, as specified in Table E-4, are to be placed inside the screen enclosure. Connectors are to be mated in accordance with number and color coding.

2.1.1.2 Diagnostic Hardware. Table E-4 specifies the equipment setup for diagnostic system checkouts. Install the appropriate diagnostic hardware into the Switching System.

NOTE

Exercise extreme care in mating connectors. JPL QA representative to verify correct connector mating (ref. Part III, para. 4.0).

2.1.2 Test Console

2.1.2.1 LAB. STD. DEV. Select the appropriate Control card in accordance with Table E-4. Install the appropriate laboratory standard device into the control board and insert the board into the Test Console front panel (ref. Part III, para. 1.0).

NOTE

All operational amplifier and comparator laboratory standard devices are the TO-99 can versions. The analog switches are flat-packs. JFET packages are TO-18, TO-71 and TO-72.

2.1.2.2 DVM RANGE. Set the DVM Range Selector switch to the type of device being tested and as specified on Table E-4.

2.1.2.3 MANUAL Mode. Place the Manual/Auto switch in the MANUAL position.

2.1.2.4 Power ON. Place the Power switch in the ON position.

2.1.2.5 Reset. Depress the Reset button until the device number readout reads "39".

2.1.2.6 Data Cables. Data cable connections between the Test Console, DVM and Ammeter are dependent upon what type of device is being screened. Set up cable connections indicated below.

(1) Operational Amplifiers and Comparators

(a) DVM Input cable connects to "TC OUTPUT" terminals.

(b) Ammeter input cable connects to "BLANK" terminals.

(2) Analog Switches and JFET

(a) DVM input cable connects to "AMM. OUTPUT" terminals.

(b) Ammeter input cable connects "TC OUTPUT" terminals.

2.1.3 Ammeter

If screening JFET or analog switches, set up the ammeter as indicated below, otherwise proceed to Step 2.1.4.

2.1.3.1 Display Rate -- MAX. Rotate the Display Rate switch to the MAX position.

2.1.3.2 Filter -- IN. Place Filter switch in the IN position.

2.1.3.3 Zero -- OPERATE. Check meter zero and place the Check/Operate switch in the OPERATE position.

2.1.3.4 Range -- AUTO. Place the Hold/Automatic switch in the AUTOMATIC position.

2.1.4 Tape Module

2.1.4.1 Load Cassette. Load the magnetic tape cassette into the Tape Module.

2.1.4.2 Rewind. Momentarily depress the Rewind switch to rewind the tape.

2.1.5 Data Terminal

2.1.5.1 Carriage Return. Operate the Carriage Return key to clear the paper in the typewriter.

2.1.5.2 Tape Punch. Press the Power switch to turn punch power ON.

2.1.5.3 Leader. Feed approximately 15cm (6 inches) of blank leader on the paper tape.

2.2 TEST SEQUENCE

2.2.1 Tape Module

2.2.1.1 ON LINE. Press the Online switch to obtain a steady "ON LINE" readout.

2.2.1.2 LINE DATA. Operate the Source switch to obtain "LINE DATA" readout.

2.2.2 Remote Head -- SYSTEM RESET.

Depress the Power On/System Reset button. The tape will run briefly and "WRITE" will appear in the Tape Module readout.

2.2.3 Test Console

2.2.3.1 AUTO. Place the Manual/Auto switch in the AUTO position.

2.2.3.2 START. Depress the Start button once to start the sequence.

NOTE

The system will sequence through the tests automatically; data will be recorded on the magnetic tape and the teletype. At the end of the test sequence, the "end of test" lamp will be illuminated on the TC and the magnetic tape will rewind automatically.

2.2.4 Tape Module -- TERM DATA

At the end of the test sequence press the Source switch to obtain "TERM DATA" on the readout.

2.2.5 Data Terminal

2.2.5.1 Leader. Feed 15cm (6 inches) paper tape leader.

2.2.5.2 Remove Tape. Remove the paper tape and hold for use in data processing if required.

2.2.5.3 Punch OFF. Turn the paper tape punch power OFF.

2.3 DATA PROCESSING

2.3.1 Remote Head -- MODEM SELECT.

Operate the Modem Select switch illuminating the indicator.

2.3.2 Data Terminal

Establish communication with the computer. Call up the current program and proceed to the question "Ready to accept diagnostic data?". Do not answer.

2.3.3 Tape Module -- LINE DATA

Depress the Source switch to obtain "LINE DATA" on the readout.

2.3.4 Data Terminal -- CTL/Q

On the keyboard simultaneously depress the CTL and Q keys.

NOTE

The Tape Module will play the data to the computer automatically and the typewriter will print the data received by the computer. At the end of the data, the tape will stop automatically at the question "Do you want to input the diagnostic data again?" Do not answer.

2.3.5 Data Terminal

Before answering the question, determine what the answer should be and proceed as directed below.

2.3.5.1 YES. If the answer is YES:

(1) Tape Module. Rewind the tape cassette by momentarily processing the Rewind switch.

(2) Answer the question YES.

(3) Recycle to Step 2.3.5.

2.3.5.2 NO. If the answer is NO:

(1) Tape Module -- TERM DATA. Press the Source switch to obtain "TERM DATA" on the module readout.

(2) Answer the question NO.

(3) After the computer completes processing the diagnostic data, sign off from the computer.

(4) Go to Step 2.3.6.

2.3.6 Remote Head -- CONSOLE SELECT

Switch the Remote Head to console position by-pressing Console Select switch; indicator will be illuminated.

2.3.7 Tape Module

2.3.7.1 Remove the tape cassette.

2.3.7.2 OFF LINE. Press the Online switch to obtain a flashing "ONLINE" readout.

2.3.8 Test Console -- POWER OFF.

Turn Test Console Power OFF.

SECTION 3

DEVICE SCREENING

3.1 TEST EQUIPMENT SETUP

Test equipment is to be set up as indicated below. Selection of equipment to be used is controlled by Table E-4.

3.1.1 Switching System

3.1.1.1 Stepper Switches. Two stepper switches, as specified in Table E-4 are to be placed inside the screen enclosure. Connectors are to be mated in accordance with number and color coding.

3.1.1.2 Mother Boards. Two Mother Boards with flight parts installed are to be installed into the Switching System (ref. Part III, para. 3.0).

3.1.1.3 Setup for Exposure. Prior to continuing, set up the exposure station as indicated below.

NOTE

Exercise extreme care in mating connectors. JPL QA representative is to verify correct connector mating (ref. Part III, para. 4.0).

(1) Set the cobalt 60 source tube array to a pitch diameter of 11.4 cm using the setup template.

(2) Set the exposure station to place the flight devices at the required distance from the source using the setup template.

(3) Set three TLD's (broad side to the source) in a plane passing through the flight devices to measure the absorbed dose.

(4) After completion of the setup close the screen enclosure by installing and securing the end wall of the enclosure.

3.1.2 Test Console

3.1.2.1 LAB. STD. DEV. Select the appropriate Control card in accordance with Table E-4. Install the appropriate laboratory standard device into the control board and insert the board into the Test Console front panel (ref. Part III, para. 1.0).

NOTE

All operational amplifier and comparator laboratory standard devices are the TO-99 can versions. The analog switches are flat-packs. JFET packages are TO-18, TO-71 and TO-72.

3.1.2.2 DVM RANGE. Set the DVM Range selector switch to the type of device being tested and as specified on Table E-4.

3.1.2.3 MANUAL Mode. Place the Manual/Auto switch in the MANUAL position.

3.1.2.4 Power ON. Place the Power switch in the ON position.

NOTE

Verify that power supply current levels are not greater than the levels specified in Table E-4.

3.1.2.5 Data Cables. Data cable connections between the Test Console, DVM and Ammeter are dependent upon what type of device is being screened. Set up cable connections as indicated below.

(1) Operational Amplifier and Comparators

(a) DVM Input cable is to be connected to "TC OUT" receptacle.

(b) Connect the Ammeter input cable to the "BLANK" receptacle.

(2) Analog Switch and JFET

(a) DVM Input cable is to be connected to "AMM. OUT" receptable.

(b) Connect the Ammeter input cable to the "TC OUT" receptable.

3.1.3 Ammeter

If screening JFET or analog switches, set up the ammeter as indicated below, otherwise proceed to Step 2.1.4.

3.1.3.1 Display Rate -- MAX. Rotate the Display Rate switch to the MAX position.

3.1.3.2 Filter -- IN. Place Filter switch in the IN position.

3.1.3.3 Zero -- OPERATE. Check meter zero and place the Check/Operate switch in the OPERATE position.

3.1.3.4 Range -- AUTO. Place the Hold/Automatic switch in the AUTOMATIC position.

3.1.4 Tape Module

3.1.4.1 Load Cassette. Load the magnetic tape cassette into the Tape Module.

3.1.4.2 Rewind. Momentarily depress the Rewind switch to rewind the tape.

3.1.5 Data Terminal

3.1.5.1 Carriage Return. Operate the Carriage Return key to clear the paper in the typewriter.

3.1.5.2 Tape Punch. Press the Power switch to turn punch power ON.

3.1.5.3 Leader. Feed approximately 15cm (6 inches) of blank leader on the paper tape.

NOTE

Allow the flight devices to warm up for 5 minutes before proceeding to Step 3.2.

3.2 PREIRRADIATION TEST SEQUENCE

This test sequence is performed to establish device acceptability prior to exposing the devices to radiation (ref. Part III, para. 5.0).

3.2.1 Remote Head -- CONSOLE SELECT.

Depress the Console Select switch, illuminating the indicator lamp.

3.2.2 Tape Module

3.2.2.1 LINE DATA. Operate the Source switch to obtain "LINE DATA" on the module readout.

3.2.2.2 ONLINE. Press the Online switch to obtain a steady "ONLINE" readout.

3.2.3 Remote Head -- RESET.

Press the Power ON/System Reset to reset the test system.

3.2.4 Test Console

3.2.4.1 AUTO. Place the Manual/Auto switch in the AUTO position.

3.2.4.2 START. Depress the Start switch once to start the test sequence.

NOTE

The system will sequence through the tests automatically, data will be recorded on the magnetic tape, paper tape and teletype. At the end of the test sequence the "end of test" lamp will be illuminated on the TC and the magnetic tape will rewind automatically.

3.2.5 Tape Module -- TERM DATA.

At end of the test sequence press the Source switch to obtain "TERM DATA" on the module readout.

3.2.6 Data Terminal

3.2.6.1 Leader. Feed 15cm (6 inches) blank paper tape leader.

3.2.6.2 Remove Tape. Remove the paper tape and label.

3.2.6.3 Punch OFF. Turn paper punch power OFF.

3.3 PREIRRADIATION DATA PROCESSING

3.3.1 Remote Head -- MODEM SELECT

Depress the Modem Select button. The Modem Select indicated will illuminate.

3.3.2 Data Terminal

Establish communication with the computer. Call up the current program and proceed to the question "Ready to accept pre-radiation data?". Do not answer.

3.3.3 Tape Module -- LINE DATA

Depress the Source switch to obtain "LINE DATA" readout.

3.3.4 Data Terminal -- CTL/Q.

Depress the CTL and Q keys simultaneously.

NOTE

> The Tape Module will play the preirradiation data to the computer automatically and the teletype will print the data received by the computer. At the end of the data the tape will stop automatically at the question "Do you want to input the pre-radiation data again?". Do not answer.

3.3.5 Data Terminal

Before answering the question determine what the answer should be and proceed as directed below.

3.3.5.1 YES. If the answer is YES:

(1) Tape Module -- REWIND. Rewind the cassette by depressing the Rewind switch momentarily.

(2) Answer the question YES.

(3) Recycle to 3.3.5.

3.3.5.2 NO. If the answer is NO:

(1) Tape Module -- TERM DATA. Depress the Source switch to obtain "TERM DATA" on the module readout.

(2) Answer the question NO.

(3) At question "What Next?"

(a) If results are acceptable, answer "5", sign off from the computer and go to 3.3.6.

(b) If the results are unacceptable, remedy the problem and:

(i) Go to 1.0 if equipment teardown was required.

(ii) Go to 3.0 if no teardown was required.

3.3.6 Remote Head -- CONSOLE SELECT

Depress Console Select switch illuminating the indicator.

3.3.7 Tape Module

3.3.7.1 Remove Tape. Remove the cassette and label per Part III, para. 9.0.

3.3.7.2 Load Tape. Rotate the cassette and reload it into the Tape Module to record on the second side. The second side is to be labeled "POST".

3.3.7.3 REWIND. Rewind the cassette by momentarily pressing the Rewind switch. The rewind process will take about 2 minutes, but it is OK to proceed while the tape is rewinding.

3.3.7.4 OFF LINE. Place the module off line by pressing the Source switch and obtaining a flashing "ON LINE" readout.

3.3.8 Test Console

3.3.8.1 MANUAL. Place the Manual/Auto switch in the MANUAL position.

3.3.8.2 RESET. Reset the steppers by depressing the Reset button until "39" appears in the device number readout.

3.4 DEVICE EXPOSURE

3.4.1 Determine the exposure time required to obtain the specified dose level. Write the time, in minutes, on the Traveler (ref. Part III, para. 10.0).

3.4.2 Set the Gammabeam 650 timer to the time determined in Step 3.4.1.

3.4.3 Select all source tubes on the Gammabeam 650 control console.

3.4.4. Verify that power supply currents do not exceed the levels called out in Table E-4.

3.4.5 Close the exposure cell.

3.4.6 Activate the source verifying that all sources are up and the system is functioning properly.

NOTE

> If problems occur in source operation, stop the exposure, keeping track of the actual time the devices were exposed. Remedy the problem and recycle to Step 3.4.

3.4.7 Approximately 3 minutes prior to completion of the exposure, set up the following equipment as indicated.

3.4.7.1 Remote Head -- CONSOLE SELECT. Verify that the Remote Head is in Console Select mode.

3.4.7.2 Data Terminal. Perform the following:

(1) Carriage Return. Operate the Return key to clear paper in the typewriter.

(2) Punch ON. Turn the paper tape punch ON.

(3) Leader. Feed approximately 15cm (6 inches) of leader on the paper tape punch.

3.4.7.3 Tape Module. Perform the following:

(1) LINE DATA. Operate the Source switch to obtain a "LINE DATA" readout.

(2) ON LINE. Operate "ONLINE" switch to obtain a steady "ON LINE" readout.

3.4.7.4 Remote Head -- RESET. Reset the system by depressing the Power ON/System Reset button.

3.5 POSTIRRADIATION TEST SEQUENCE

When the device exposure is complete start the postirradiation test sequence immediately.

3.5.1 Test Console

3.5.1.1 AUTO. Place the Manual/Auto switch in the AUTO position.

3.5.1.2 START. Press the Start switch once to start the test sequence.

NOTE

The system will sequence through the tests automatically, data will be recorded on the magnetic tape, paper tape and teletype. At the end of the test sequence the "end of test" lamp will be illuminated on the test console and the magnetic tape will rewind automatically.

3.5.2 Tape Module -- TERM DATA

At the end of the test sequence place the module in TERM DATA mode by depressing the Source switch to obtain a "TERM DATA" readout.

3.5.3 Data Terminal

3.5.3.1 Leader. Feed 15cm (6 inches) blank paper tape leader.

3.3.5.2 Remove Tape. Remove the punched tape and label.

3.3.5.3 Punch OFF. Turn paper tape punch OFF.

3.6 POSTIRRADIATION DATA PROCESSING

3.6.1 Remote Head -- MODEM SELECT

Operate the Modem Select switch to illuminate the indicator.

3.6.2 Data Terminal

Establish communications with the computer, call up the current program and proceed to the question "Ready to accept post-radiation data?". Do not answer.

3.6.3 Tape Module -- LINE DATA

Operate the Source switch to obtain "LINE DATA" on the module readout.

3.6.4 Data Terminal -- CTL/Q

Simultaneously depress the CTL and Q keys on the typewriter keyboard.

NOTE

> The Tape Module will play the post-irradiation data to the computer automatically and the teletype will print the data received by the computer. At the end of the data the tape will stop automatically at the question "Do you want to input post-radiation data again?". Do not answer.

3.6.5 Data Terminal

Before answering the question determine what the answer should be and proceed as indicated below.

3.6.5.1 YES. If the answer is YES:

(1) Tape Module -- REWIND. Rewind the cassette.

(2) Answer the question YES.

(3) Recycle to 3.6.5.

3.6.5.2 NO. If the answer is NO:

(1) Tape Module -- TERM DATA. Function Source switch to obtain "TERM DATA" readout.

(2) Answer question NO.

(3) After computer completes processing the data request final printout twice ("7", "7"), stop test ("5") and sign off from the computer (ref. Part III, para. 15.0).

3.6.6 Tape Module

3.6.6.1 Remove Tape. Remove the tape cassette and verify that it is labeled per Part III, para. 14.0.

3.6.7 Test Console

3.6.7.1 MANUAL. Place the Manual/Auto switch in the MANUAL position.

3.6.7.2 Power OFF. Turn console power OFF.

3.6.8 Device Anneal

From this point on device handling shall be controlled by Part III starting with para. 16.0.

Table E-4. Test Setup Matrix

DEVICE TYPE	SET-UP					MAXIMUM POWER SUPPLY CURRENT, mA					
	DEV. TYPE CODE	DVM RANGE	MOTHER BOARD/ CONTROL BOARD	ADPTR	STPR	+15V	+10V	+40V	-20V	+12V	-18V
LM101AF	11	OA	OA	3	OA	75	NA	NA	NA	NA	NA
LM101AH	10	OA	OA	2A	OA	75	NA	NA	NA	NA	NA
LM111F	15	COMP	COMP	10	OA	150	5	NA	NA	NA	NA
LM111H	14	COMP	COMP	9	OA	150	5	NA	NA	NA	NA
OA DIAGNOSTIC	10	OA	OA DIAG	NA	OA	NA	NA	NA	NA	NA	NA
2N5556	22	JFET	JFET-I	NA	AS	<1	NA	NA	NA	NA	NA
AS DIAGNOSTIC	01	AS	AS	1	AS	NA	NA	NA	NA	NA	NA
COMP DIAGNOSTIC	10	OA	OA DIAG	NA	OA	NA	NA	NA	NA	NA	NA
DG129A	01	AS	AS	1	AS	NA	<1	NA	NA	170	100
DG133A	02	AS	AS	1	AS	NA	<1	NA	NA	170	100
DG141A	03	AS	AS	1	AS	NA	L1	NA	NA	170	100
2N5196	20	JFET	JFET-II	NA	AS	NA	<1	NA	NA	NA	NA
2N5520	21	JFET	JFET-II	NA	AS	NA	<1	NA	NA	NA	NA
2N4856	24	JFET	JFET-I	NA	AS	NA	NA	NA	< 1	NA	NA

NOTE: OA = Operational Amplifier; COMP = Voltage Comparator; AS = Analog Switch; JFET = Junction Field Effect Transistor

PART III

QUALITY ASSURANCE REQUIREMENTS FOR IRAN SCREENING PROGRAM

GENERAL

During the IRAN test operation, all flight devices shall be handled using cotton gloves and/or tweezers. At no time shall the flight parts be handled by uncovered hands. Wrist-stats shall be used at all times when handling the parts.

When the test parts are removed from packing containers they shall be handled over a bench having at least 2.5 cm (1 inch) foam padding. When not in a test cycle, the test devices shall be stored in sealed cardboard or plastic boxes, which will be taped shut and placed in a bonded stores area. The parts traveler, shown in Figure E-3, shall be used as a guide for Quality Assurance operation. The individual operational steps required in handling parts are shown in Figure E-1 and discussed in detail in the subsequent paragraphs.

The JPL QA representative, using a 3M static charge meter, shall periodically verify the acceptability of work area and bench test area prior to the IRAN screen test operation.

1.0 LOG-IN PARTS AND INITIATE TEST TRAVELER

Upon arrival of each lot of IRAN screening parts at Hughes Fullerton test facility, a Master Log and Screening Traveler shall be initiated for that lot. Take the parts out of shipping container on the designated bench top area and perform the following operations:

(1) Identify and record the following information on the Master Log:

- (a) Part Type
- (b) Manufacturer
- (c) Quality
- (d) Receipt date
- (e) JPL shipper number
- (f) Lot number
- (g) Date code
- (h) Diffusion run number (if available record in remarks column)

(2) Have the JPL QA representative initial and stamp item number 1 of the traveler. The responsible HAC personnel shall also initial and date item on the traveler.

(3) JPL QA representative shall perform a microscopic (10X) inspection of the leads on a sample of five (5) devices from each lot.

(4) Laboratory Standard devices shall be used as control devices which shall not be irradiated or annealed. The Laboratory Standards devices shall not be returned to JPL as a part of the lot. The control unit shall be electrically measured every time the test devices are measured to check the test setup.

2.0 LOAD CONTACTORS

Select the appropriate contactors (adaptors) as specified in Table E-4. Load the empty adaptors onto the Mother Boards. JPL QA representative is to verify correct orientation of pin 1 on the adaptor. Item 2 on the traveler is to be signed off by the JPL QA and HAC representatives.

3.0 LOAD MOTHER BOARDS

The flight device containers shall be opened by cutting the tape (tape shall not be stripped from boxes) and the devices placed on the padded bench ready for loading onto the Mother Boards. As each device is loaded onto the Mother Board the following items shall be performed:

(1) Verify that the device is correctly oriented with the device carrier (Figure E-7).

(2) The Mother board shall be loaded with the lowest serial number in socket number two; the next highest serial number into socket number three, etc. This sequence shall be carried out until all test parts are loaded, or the Mother Board is full.

(3) As a device is loaded into a Mother Board socket, the device serial number shall be recorded opposite the appropriate socket number on the Data Sheet (see Figure E-6). Devices received without serial numbers shall be serialized prior to loading on the Mother board.

(4) Prior to loading devices onto the Mother Boards (MB) the MB is to be connected to the Supply Current Test Fixture (SCTF). The SCTF is to be used to test the supply current drawn by the devices as they are loaded onto the MB. As each device is loaded onto the MB

a current test is made and results are compared with the allowed supply current flow as indicated in Table E-4.

(5) If for any current test the value measured exceeds the value specified in Table E-4 proceed as follows:

(a) Remove the last device installed and check the device orientation in the carrier or socket. If the device/carrier orientation was incorrect, the JPL QA representative shall remove the device and reinstall it correctly. Then load the device onto the MB again and test the supply current again.

(b) If the measured current agrees with the allowed current in Table E-4, leave the device in the MB, prepare an AVO describing the problem and contact the cognizant JPL technical representative for instructions prior to testing.

(c) If the excessive current can't be eliminated remove the device from the test lot, prepare an AVO describing the problem and contact the cognizant JPL representative.

(6) Continue sequentially loading devices onto the MB and testing the supply current with the SCTF until all devices to be screened are loaded onto MB's.

The JPL QA representative shall verify this operation and initial and stamp item 3 on the traveler. The responsible HAC personnel shall also initial and date item 3 on the traveler (Figure E-3).

4.0 SYSTEM CHECKOUT

Before a loaded Mother Board is placed in the radiation test fixture, the appropriate Diagnostic Card shall be utilized. The Diagnostic Card shall be placed in the Mother Board socket and the system operation verified per paragraph 2.0, Part II of this procedure.

Prior to system checkout the JPL QA representative shall verify correct mating of all test equipment connectors.

After verification and approval of system operation by the JPL QA representative, the QA representative shall initial and stamp item number 4 on the traveler. The responsible HAC personnel shall also initial and date item number 4 on the traveler.

5.0 PRE-IRRADIATION MEASUREMENTS

Install the loaded Mother Boards into the switching system chassis and initiate parameter testing as described in Part II of this procedure.

6.0 REVIEW PRINTER DATA

The printer tape output shall be inspected for abnormalities, such as missing and/or obviously incorrect data, prior to initiation of irradiation.

When the data is deemed acceptable, The JPL QA representative shall initial and stamp item 6 on the traveler. The responsible HAC personnel shall also date and initial item 6 on the traveler.

7.0 INPUT PARTS I. D. TO COMPUTER

Communication with the HAC Facility HP 3000 computer shall be initiated through the computer terminal, and acoustic coupler. Information input to the computer shall consist of the operator typing answers from the terminal keyboard in response to questions from the computer.

The computer shall indicate to the operator when the program is prepared to receive data from the search tape.

8.0 INPUT TEST DATA TO COMPUTER

The paper punch tape generated in item 6 shall now be inserted into the tape reader/punch unit attached to the teletype terminal. When alignment of the punch tape on the tape drive sprocket has been verified, and the feed cover securely latched, the tape reader/punch unit shall be activated by moving the lever switch to the "READY" position. When ready to input data, type "RESUME" followed by a line return, the tape will be read in automatically under computer control.

After the tape has fed through reader/punch unit the tape shall be removed from the unit and set aside pending verification of parameter value calculations.

9.0 REVIEW COMPUTER OUTPUT

The calculated parameter values returned to the terminal shall be examined for errors or devices which do not fall within the specification values. In the event of either occurrence, a second pre-irradiation data run shall be performed for verification. In the event of non-verification, a third data run shall be made. If no agreement between the three data runs can be established, the test shall be aborted to identify and remedy the problem. After the problem has been remedied, a new data run shall be performed.

After verification of parameter calculations the data tape shall be labeled as pre-irradiation data. The device type, lot number and irradiation date shall be recorded on the tape, and the tape stored in a plastic box. The plastic box shall be labeled with the following information:

(1) Part type

(2) Manufacturer

(3) Lot number

(4) Date code

(5) Irradiation test date

(6) Responsible HAC personnel initials.

The plastic box containing the punch tape shall remain in the test area pending the addition of the post-irradiation data tape.

The JPL QA representative shall initial and stamp item 9 on the traveler. The responsible HAC test personnel shall also initial and date item 9 on the traveler.

10.0 EXPOSE DEVICES

Verify that the Gammabeam control console has been selected for automatic operation, the timer has been set for the required time, and all sources have been selected for use. Start the irradiation run and verify that all sources have been raised.

At the end of the irradiation run the JPL QA representative shall initial and stamp item 10 of the traveler. The HAC responsible test personnel shall initial and date item 10 on the traveler and enter the required information concerning total dose and dose rate.

11.0 POST-IRRADIATION MEASUREMENTS

The post-irradiation procedure shall be identical to the pre-irradiation procedure called out in item 5.

The JPL QA representative shall initial and stamp item 11 of the traveler. The responsible HAC test personnel shall also initial and date item 11 on the traveler.

12.0 REVIEW PRINTER DATA

The same procedure called out in item 6 shall be used.

The JPL QA representative shall initial and stamp item 12 and date item 12 on the traveler.

13.0 INPUT TEST DATA TO COMPUTER

The same procedure called out in item 8 shall be used.

14.0 REVIEW COMPUTER OUTPUT

The same procedure called out in item 9 shall be used with the exception that the punch tape shall be marked as post-irradiation.

The plastic box containing the data tapes shall be returned to bonded stores, and become a part of the test record.

15.0 REQUEST COPIES OF DATA

Prior to sign off from the computer request two copies of raw and final data.

A. <u>Data Handling</u>

Pick up data at computer terminal, obtain six reduced copies and notify cognizant JPL representative that the data is available.

16.0 UNLOAD MOTHER BOARDS

A. <u>Integrated Circuits</u>

Remove the Mother Boards from the switching system chassis and place them on the designated work bench area. Remove loaded contactors from the Mother Board and place them in sequential serial number order on the bench top.

B. <u>Transistors</u>

Remove Mother Boards from switching system and return them to the bonded stores area. These devices shall not be annealed. Therefore additional handling procedures shall skip to para. 23.

17.0 REMOVE PARTS FROM CONTACTORS

Remove parts from contactors wearing cotton gloves and wrist-stats, and place them on the bench, maintaining sequential serial number order. Gather the empty contactors and store them in their designated box in the supply cabinet.

18.0 PLACE PARTS IN ANNEALING TRAYS

Place parts on the vented annealing trays maintaining sequential serial number order. The part with the lowest serial number shall be placed in the upper left hand corner of the tray and continue in horizontal rows left to right and then toward the operator. When placing the test devices on the vented tray maintain a minimum of 1/16 inch separation between device carriers, to insure an even air flow and prevent hot spots.

19.0 LOG PARTS INTO ANNEAL

The Anneal Data Sheet shall be maintained in chronological order, and attached to the environmental chamber indicating which part types are located inside the chamber and the date due out. The Anneal Data Sheet is shown in Fig. E-8. The required information will be filled out on the anneal data sheet and the devices will be on standby for annealing.

The JPL QA representative shall initial and stamp item 19 on the traveler. The HAC responsible test personnel shall also date and initial item 19 of the traveler.

20.0 POST-IRRADIATION ANNEALING

Upon initial start-up of the temperature ovens, the following steps shall be performed:

(1) Set fail-safe thermostat to 155°C (JPL-QA shall monitor).

(2) Open the nitrogen (N_2) valve and adjust the gas flow rate to $4 ft^3/hr$. for 30 min before application of heat.

(3) Set the oven temperature to 150°C and activate the heaters.

After verification that the proper temperature has been reached, the following steps shall be used for subsequent annealing of irradiated parts.

(1) Install bake trays in the temperature chamber.

(2) Close door and secure by means of the two screw-down handles provided.

(3) Assure gas flow of $4 ft^3/hr$.

For addition and/or removal of parts the following steps shall be used:

(1) Addition or removal of parts shall be as rapid as possible to reduce heat loss.

(2) Addition or removal of parts shall take place only once per day.

(3) Determine which bake trays are due to be removed prior to opening the chamber.

(4) Open temperature chamber door by loosening the two screw-down handles.

(5) Add and/or remove parts as required.

(6) Close door and secure with the two screw-down handles.

(7) Record time-in or out on the lot traveler.

(8) Assure that the gas flow rate remains at $4 ft^3/hr$.

(9) Check level of N_2 remaining in bottles and replace any bottle that has less than 10% of the original volume remaining.

(10) Notify JPL that the parts have entered the anneal cycle.

Test parts shall be annealed in the temperature for a minimum of 96 hrs at $150 \pm 3^{\circ}C$. In the event that parts are scheduled to be removed from the annealing cycle on Friday evening or during a weekend the parts shall remain in the temperature chamber at elevated temperature until the following working day at which time the parts shall be removed from the chamber. Prior to personnel leaving for the weekend all N_2 bottle levels shall be checked to insure sufficient volume of gas to carry through the weekend.

21.0 LOG PARTS OUT OF ANNEAL

After the parts have been removed from the temperature chamber the trays shall be placed on a grounded heat sink until cool. Then place the trays on the foam pad on the designated area of the bench. The total anneal time shall be determined from the anneal data sheet and entered on the parts traveler in item 21. The JPL QA representative shall perform a microscopic inspection of the leads on a sample of five devices of each lot using a 10X power microscope. The JPL QA representative shall initial and stamp item number 21 of the traveler. The responsible HAC personnel shall also initial and date item number 21 on the traveler.

22.0 NOTIFY JPL OF COMPLETION OF ANNEALING

23.0 REPACKAGE PARTS

The annealed parts shall be removed from the bake tray using cotton gloves and wrist-stats, and placed in sequential serial number order on the designated work bench area. Obtain the original individual shipping containers from the storage area, match device and container serial number, and place containers adjacent to the annealed parts. The JPL QA representative shall apply a yellow sticker and blue seal to each part container. The JPL QA representative shall stamp each blue seal with the I.P. stamp using black ink. The part containers shall be placed in the original shipping container and the container shall receive a yellow sticker and blue seal with I.P. stamp, by JPL QA representative.

NOTE

In the event the original containers cannot be used JPL will furnish new anti-static charge containers and packaging materials.

JPL QA representative shall initial and stamp item 23 on the traveler. The HAC responsible test personnel shall also date and initial item 23 on the traveler.

24.0 LOG OUT PARTS

Complete the Master Log and Screening Traveler. Notify JPL that the parts are available for pickup. JPL QA representative shall initial and stamp item 24 on the traveler. The HAC responsible test personnel shall also date and initial item 24 on the traveler.

Complete AVO to identify which screened devices are to be removed from the screened lot for further test under the re-irradiate program.

25.0 RELEASE PARTS

The responsible HAC test personnel shall fill out the Hughes Property Accountability Document (PAD-Form 11052). Upon pickup by JPL personnel the following items shall be noted.

(1) JPL QA representative shall stamp and initial item 25 of the traveler.

(2) HAC personnel shall date and initial item 25 of the traveler.

(3) The JPL pickup personnel shall sign and date the PAD accepting delivery of parts and data.

(4) Re-irradiate devices are to be handled as a package separate from the screened lot and identified on the PAD.

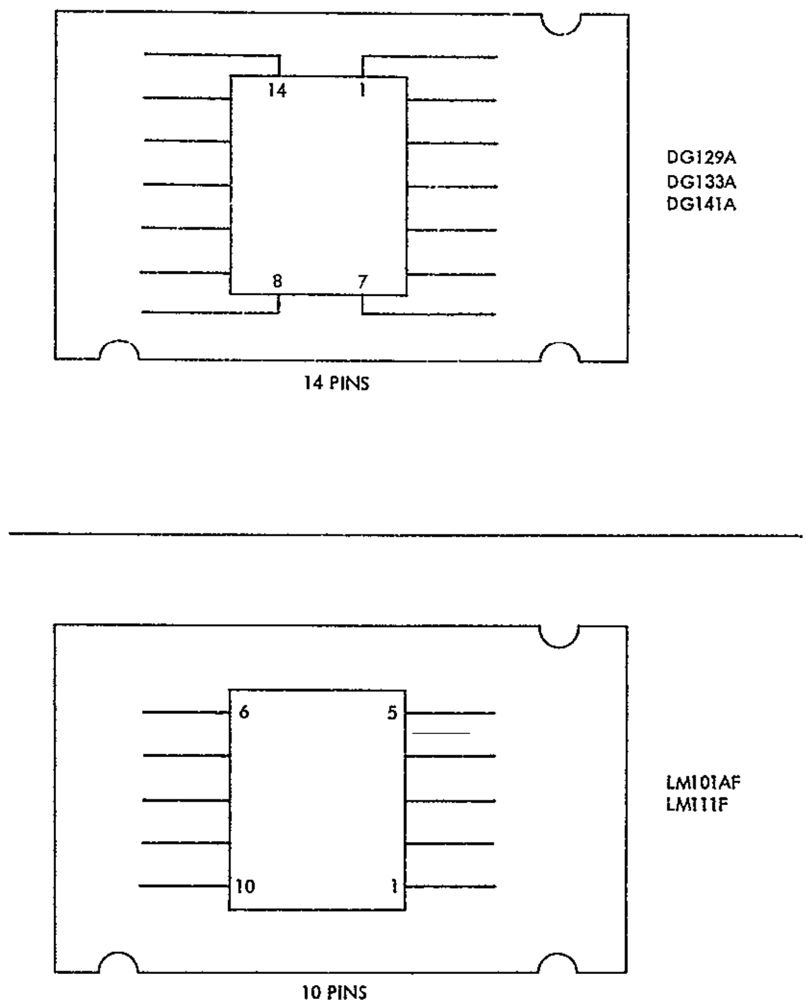

Figure E-7. Flatpack Device/Carrier Orientation

Part Type	Lot No.	Date/ Run No.	Qty.	Time In (Date - hrs.)	ANNEAL DATA (OVEN) Expected Time Out (Date - hrs.)	Actual Time Out (Date - hrs.)	Accumulated Anneal time

Figure E-8. Sample Anneal Data Sheet

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16. Abstract

Test requirements and procedures for the Voyager electronic parts radiation program are set forth in detail as Appendixes to JPL Publication 77-41, Volume I. Together, the two volumes describe the program phiolosophy, radiation environment, device hardening efforts, and radiation test methods. Test results of more than 200 device types are summarized in Volume I.

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